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The Zambezi River Basin

A Multi-Sector Investment Opportunities Analysis

VOLUME 3

State of the Basin

THE WORLD BANK

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Volume 3
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1818 H Street NW
Washington DC 20433
Telephone: 202-473-1000
Internet: www.worldbank.org
E-mail: feedback@worldbank.org

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Currency Equivalents

Against U.S. dollar

	Angolan new kwanza Kz	Botswana pula P	Euro €	Malawi kwacha MK	Mozambique metical Mt	Namibia dollar N$	Tanzania schilling T Sh	Zambia kwacha K	Zimbabwe dollar Z$
2000	5.94	5.09	1.08	47.10	15.41	6.95	799.27	2,830.00	44.40
2001	11.51	5.72	1.12	70.03	20.33	8.62	876.59	2,845.37	55.26
2002	32.41	6.26	1.06	76.24	23.24	10.52	965.27	4,360.81	55.29
2003	57.65	4.91	0.89	95.24	23.31	7.57	1,036.79	4,841.94	577.19
2004	57.65	4.68	0.80	106.74	22.03	6.46	1,088.20	4,750.53	4,499.18
2005	74.90	5.11	0.80	116.84	22.85	6.36	1,125.36	4,432.60	21,566.90
2006	86.85	5.83	0.80	135.54	25.93	6.77	1,251.28	3,586.09	58,289.86
2007	77.38	6.15	0.73	139.72	25.56	7.06	1,241.24	3,996.41	9,296.66
2008	74.97	6.84	0.68	140.91	24.14	8.25	1,199.75	3,746.63	2,638,293,338
2009	77.97	7.14	0.72	141.75	26.87	8.43	1,324.34	5,049.15	21,830,975.04

Units

1 km^3 = 1,000 hm^3 = 1 billion m^3

1 m^3/s = 31.54 hm^3/year = 0.033 km^3/year

1 l/s/ha = 86.4 m^3/day/ha = 8.6 mm/day

1 gigawatt hour (GWh) = 1,000 MWh = 1,000,000 KWh = 1,000,000,000 Wh

1 km^2 = 100 ha

Unless otherwise specified, the symbol $ refers to U.S. dollars.

Acknowledgments

This report provides a summary of the series of reports and documents prepared to assess the water resources development options and benefits of cooperation among the riparian countries in the Zambezi River Basin. The effort was led by a Bank Team consisting of Vahid Alavian (Team Leader), Marcus Wishart, Louise Croneborg, Rimma Dankova, K. Anna Kim, and Lucson Pierre-Charles. The initial Team Leader for this work was Len Abrams, now retired. The Multi-Sector Investment Opportunities Analysis is based on a series of reports and model simulations prepared by a consortium of BRLi and Niras. The consultants served as partners and members of the team during the course of this work.

The Team gratefully acknowledges the contributions by representatives of the riparian countries of the Zambezi River Basin, the Southern Africa Development Community (SADC) Water Division, and other international development partners. Their participation and input at the regional meeting in Gaborone, Botswana in July 2009, and at the eight national consultation workshops held between September and December 2009 is much appreciated. The financial contribution and support from the Swedish International Development Cooperation Agency (Sida) and the Government of Norway are acknowledged with appreciation.

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Abbreviations and Acronyms

AAP	Africa Action Plan
ACP	Agricultural Commercialization Program (Zambia)
AF	artificial flooding
AMD	acid mine drainage
AMU	Arab Maghreb Union
ARA	Administração Regional de Águas (Regional Water Administrations, Mozambique)
ASDP	Agricultural Sector Development Program (Tanzania)
ASDS	Agricultural Sector Development Strategy (Tanzania)
AU	African Union
BIPP	bankable investment project profile
BOD	biological oxygen demand
BOS	Bureau of Standards
BPC	Botswana Power Corporation
CAADP	Comprehensive Africa Agriculture Development Program
CBA	cost benefit analysis
CEC	Copperbelt Energy Corporation PLC
CEMAC	Central African Economic and Monetary Community
CEN-SAD	Community of Sahel-Saharan States
CEPGL	Economic Community of the Great Lakes Countries
COMESA	Common Market for Eastern and Southern Africa
CPC	Climate Prediction Center
CPFAT	Centro Provincial de Formação Agrária de Tete (Mozambique)
CRU	Climate Research Unit
CS	current situation
CSCO	current situation with coordinated operation
CSNC	current situation without coordinated operation
CVRD	Companhia Vale do Rio Doce (Brazil)
DMC	Drought Monitoring Center
DMU	Disaster Management Unit
DNA	Direcção Nacional de Águas (National Directorate of Water, Mozambique)
DNSA	Direcção Nacional de Extensão Agrária (National Directorate of Agrarian Services, Mozambique)
DPA	Provincial Directorate of Water
DRC	Democratic Republic of Congo
DSS	decision support system
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EAC	East African Community
ECCAS	Economic Community of Central African States
ECMWF	European Center for Medium Range Weather Forecast
ECOWAS	Economic Community of West African States
ECP	Estratégia de Combate à Pobreza (Poverty Reduction Strategy, Angola)
ECZ	Environmental Council of Zambia
EdM	Electricidade de Moçambique (Electricity of Mozambique, Mozambique)
EIA	Environmental Impact Assessment

EIRR	economic internal rate of return
ENE	Empresa Nacional de Electricidad (National Electricity Company, Angola)
ESCOM	Electricity Supply Corporation of Malawi
ESIA	Environmental and Social Impact Assessment
ETo	reference evapotranspiration
ETP	evapotranspiration
EU	European Union
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
EUS	epizootic ulcerative syndrome
FAO	Food and Agriculture Organization
FSL	full supply level
GDP	gross domestic product
GMA	Game Management Area
GPZ	Gabinete do Plano de Desenvolvimento da Região do Zambeze (Office of Development Planning for the Zambezi Region, Mozambique)
GWh	gigawatt hour
ha	hectare
HCB	HidroEléctrica de Cahora Bassa (Cahora Bassa Hydroelectrics, Mozambique)
HEC	Hydrologic Engineering Center
HIPC	Heavily Indebted Poor Countries Initiative
HLI	high-level irrigation
HLIC	HLI with cooperation
hm^3	Cubic hectometer
HPP	hydropower plant
HRWL	high reservoir water level
HYCOS	hydrological cycle observation system
I&C	information and communication
IBRD	International Bank for Reconstruction and Development
ICM	Integrated Committee of Ministers
ICTs	information and communication technologies
IDF	irrigation development fund
IGAD	Inter-Governmental Authority on Development
IMF	International Monetary Fund
INAM	Instituto Nacional de Meteorologia (National Institute of Meteorology, Mozambique)
IOC	Indian Ocean Commission
IP	identified project (for irrigation)
IPC	IP with cooperation
IPCC	Intergovernmental Panel on Climate Change
IRR	internal rate of return
ITT	Itezhi Tezhi Dam
IUCN	International Union for Conservation of Nature
IWRM	integrated water resources management
JICA	Japan International Cooperation Agency
JOTC	Joint Operation Technical Committee
KAZA TFCA	Kavango-Zambezi Transfrontier Conservation Area
kg/ha	kilogram per hectare
KGL	Kafue Gorge Lower Dam
KGU	Kafue Gorge Upper Dam
km^3	cubic kilometers
KWh	kilowatt hour
l/s	liters per second
LEC	Lesotho Electricity Corporation
LRRP	Land Reform and Resettlement Program (Zimbabwe)
LRWL	low reservoir water level
LSL	low supply level
m^3/s	cubic meters per second
MACO	Ministry of Agriculture and Cooperatives (Zambia)
MAP	mean annual precipitation
MAWF	Ministry of Agriculture, Water and Forestry

MASL	minimum active storage level
MDG	Millennium Development Goal
MDRI	Multilateral Debt Relief Initiative
MEA	Ministry of Energy and Water
MERP	Millennium Economic Recovery Program (Zimbabwe)
MFL	minimum flow level
mg/l	milligrams per liter
MKUKUTA	Poverty Reduction Strategy for Mainland Tanzania (kiswahili acronym)
mm/yr	millimeters per year
MMEWR	Ministry of Minerals, Energy and Water Resources
MOL	minimum operating level
MOPH	Ministry of Public Works and Housing
MoU	memorandum of understanding
MPRSP	Malawi Poverty Reduction Strategy Paper
MRU	Mano River Union
MSIOA	Multi-Sector Investment Opportunities Analysis
MW	megawatt
MWh	megawatt hour
NAMPAADD	National Master Plan for Arable Agriculture and Dairy Development (Botswana)
NAP	national agriculture policy
NDMO	National Disaster Management Office
NDP(s)	national development plan(s)
NDP2	National Development Plan 2
NEPAD	New Partnership for Africa's Development
NERP	National Economic Revival Program (Zimbabwe)
NIP	national irrigation plan
NMHS	National Meteorological and Hydrological Services
NMTIPs	national medium-term investment programs
NOAA	National Oceanic and Atmospheric Administration
NPV	net present value
NSC	north–south carrier
NSC	National Steering Committee
NSGRP	National Strategy for Growth and Reduction of Poverty (Tanzania)
NWSDS	National Water Sector Development Strategy (Tanzania)
ODA	official development assistance
OWE	open water evaporation
PAEI	Política Agrária e Estratégias de Implementação (Agriculture Policy and Implementation Strategy, Mozambique)
PAR	population at risk
PARPA	Plano de Acção para a Redução da Pobreza Absoluta (Poverty Reduction Support Strategy, Mozambique)
PARPA II	Plano de Acção para a Redução da Pobreza Absoluta II (2nd Poverty Reduction Support Strategy, Mozambique)
PASS II	Poverty Assessment Study Survey II
PFM	public financial management
PPEI	Política Pesqueira e Estratégias de Implementação (Fishery Policy and Implementation Strategy, Mozambique)
ppm	parts per million
PPP	purchasing power parity
ProAgri	Promoção de Desenvolvimento Agrário (National Agricultural Development Program, Mozambique)
PRSP	poverty reduction strategy paper
PSIP	program and system information protocol
RBO	river basin organization
RBZ	Reserve Bank of Zimbabwe
RCC	roller-compacted concrete
REC	regional economic communities
RIAS	Regional Integration Assistance Strategy
R-o-R	run-of-the-river
RSA	Republic of South Africa
RSAP	Regional Strategic Action Plan
SACU	Southern African Customs Union
SADC	Southern African Development Community
SADC-WD	SADC Water Division

SAPP	Southern African Power Pool
SARCOF	Southern African Climate Outlook Forum
SEA	strategic environmental assessment
SEB	Swaziland Electricity Board
SEDAC	Socioeconomic Data and Applications Center
SIDA	Swedish International Development Cooperation Agency
SIGFE	Sistema Integrado de Gestão Financeira do Estado (Integrated Financial Management System, Angola)
SMEC	Snowy Mountains Engineering Corporation
SNEL	Société Nationale d'Électricité (National Electricity Company, Democratic Republic of Congo)
SSIDS	small-scale irrigation development study
SWOT	strengths, weaknesses, opportunities, and threats
t/yr	tons/year
TANESCO	Tanzania Electric Supply Company
TVA	Tennessee Valley Authority (United States)
TWL	tail water level
UK	United Kingdom
UN/ISDR	United Nations Inter Agency International Strategy for Disaster Reduction
UNDP	United Nations Development Program
UNECA	United Nations Economic Commission for Africa
UNESCO	United Nations Educational, Scientific and Cultural Organization
US$	United States dollar
USAID	United States Agency for International Development
USGS	U.S. Geological Survey
VSAM	Visão do Sector Agrário em Moçambique (Mozambique)
WAEMU	West African Economic and Monetary Union
WAP	Water Apportionment Board
WASP	Web Analytics Solution Profiler
WFP	World Food Program
WHO	World Health Organization
WMO	World Meteorological Organization
WRC	Water Resources Commission
WTO	World Trade Organization
WTTC	World Travel and Tourism Council
ZACBASE	Zambezi River database
ZACPLAN	Action Plan for the Environmentally Sound Management of the Common Zambezi River System
ZACPRO	Zambezi Action Project
ZAMCOM	Zambezi River Watercourse Commission
ZAMFUND	Zambezi Trust Fund
ZAMSEC	ZAMCOM Secretariat
ZAMSTRAT	Integrated Water Resources Management Strategy and Implementation Plan for the Zambezi River Basin
ZAMTEC	ZAMCOM Technical Committee
ZAMWIS	Zambezi Water Information System
ZAPF	Zimbabwe's Agriculture Policy Framework
ZCCM	Zambia Consolidated Copper Mines Ltd
ZESA	Zimbabwe Electricity Supply Authority
ZESCO	Zambia Electricity Supply Corporation
ZINWA	Zimbabwe National Water Authority
ZRA	Zambezi River Authority
ZRB	Zambezi River Basin
ZVAC	Zambia Vulnerability Assessment Committee

1

The Zambezi River Basin: Background and Context

The Zambezi River Basin (ZRB) is one of the most diverse and valuable natural resources in Africa. Its waters are critical to sustainable economic growth and poverty reduction in the region. In addition to meeting the basic needs of some 30 million people and sustaining a rich and diverse natural environment, the river plays a central role in the economies of the eight riparian countries—Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia, and Zimbabwe. It provides important environmental goods and services to the region and is essential to regional food security and hydropower production. Because the Zambezi River Basin is characterized by extreme climatic variability, the River and its tributaries are subject to a cycle of floods and droughts that have devastating effects on the people and economies of the region, especially the poorest members of the population.

1.1 MOTIVATION FOR THIS ANALYSIS

Despite the regional importance of the ZRB, few improvements have been made in the management of its water resources over the past 30 years. Differences in post-independence development strategies and in the political economy of the riparian countries, as well as the diverse physical characteristics of the Basin, have led to approaches to water resources development that have remained primarily unilateral.

Better management and cooperative development of the Basin's water resources could significantly increase agricultural yields, hydropower outputs, and economic opportunities. Collaboration has the potential to increase the efficiency of water use, strengthen environmental sustainability, improve regulation of the demands made on natural resources, and enable greater mitigation of the impact of droughts and floods. Seen in this light, cooperative river basin development and management not only provide a mechanism for increasing the productivity and sustainability of the river system, but also provide a potential platform for accelerated regional economic growth, cooperation, and stability within the wider Southern Africa Development Community (SADC).

The World Bank, other international financial institutions and development partners have a diverse portfolio of investments and support programs in the countries that share the ZRB. Still lacking, however, is a sound analytical foundation for a coordinated strategy that can optimize the Basin's investment potential and promote cooperative development in support of sustainable economic growth and poverty alleviation.

The overall objective of the Zambezi River Multi-Sector Investment Opportunity Analysis (MSIOA) is to illustrate the benefits of cooperation among the riparian countries in the ZRB through a multi-sectoral economic evaluation of water resources development, management options and scenarios—from both national and basin-wide perspectives. The analytical framework was designed in consultation with the riparian countries, SADC Water Division (SADC-WD) and development partners in line with the Zambezi Action Plan Project 6, Phase II (ZACPRO 6.2). It is hoped that the findings, together with the Integrated Water Resources Management Strategy and Implementation Plan for the Zambezi River Basin that was developed under ZACPRO 6.2 (2008), would contribute to development, environmental sustainability, and poverty alleviation in the region.

In this analysis, the following development paths have been assessed through a series of scenarios.

- *Coordinated operation of existing hydropower facilities, either basin-wide or in clusters.* By how much could hydropower generation increase if existing projects were coordinated? What is the potential impact of coordination on other water users?
- *Development of the hydropower sector as envisioned in plans for the Southern African Power Pool (SAPP).* What is the development potential of the hydropower sector? How would its expansion affect the environment (wetlands in particular), irrigation, tourism, and other sectors? What gains could be expected from the coordinated operation of new hydropower facilities?
- *Development of the irrigation sector through unilateral or cooperative implementation of projects identified by the riparian countries.* How might the development of irrigation affect the environment (wetlands), hydropower, tourism, and other sectors? What incremental gain could be expected from cooperative as opposed to unilateral development of irrigation schemes?
- *Flood management, particularly in the Lower Zambezi and the Zambezi Delta.* What options exist to permit partial restoration of natural floods and to reduce flood risks downstream from Cahora Bassa Dam? How would those options affect the use of the existing and potential hydropower and irrigation infrastructure on the Zambezi River?
- *Effects of other projects using the waters of the Zambezi River* (e.g., transfers out of the Basin for industrial uses). How might these projects affect the environment (wetlands), hydropower, irrigation, and tourism?

Within the context of an integrated approach to the development and management of water resources, all water-related sectors are important. This analysis, however, focuses on hydropower and irrigation because of their special potential to stimulate growth in the economies of the region. Other demands for water—for potable water, environmental sustainability, tourism, fisheries, and navigation, for example—are assumed as givens. Limitations of assigning economic value to non-economic water users, such as ecosystems, are noted. To the degree allowed by the available, published information, they are incorporated into the analysis as non-negotiable.

The initial findings and the various drafts of this analysis were discussed at a regional workshop and at individual country consultations with all riparian countries. Also involved in these consultations were SADC, the international development partners active in the Basin, and other interested parties. The final draft version was shared with the riparian countries as well for comments before finalization. The Swedish International Development Cooperation Agency and the Government of Norway provided financial support.

This report consists of four volumes:

Volume 1: Summary Report
Volume 2: Basin Development Scenarios
Volume 3: State of the Basin
Volume 4: Modeling, Analysis, and Input Data

This section (1.1–1.5) appears as an introduction to all four volumes.

1.2 SUMMARY OF FINDINGS

The ZRB and its rich resources present ample opportunities for sustainable, cooperative investment in hydropower and irrigated agriculture. With cooperation and coordinated operation of the existing hydropower facilities found in the Basin, firm energy generation can potentially increase by seven percent, adding a value of $585 million over a 30-year period with essentially no major infrastructure investment.

Development of the hydropower sector according to the generation plan of the SAPP (NEXANT 2007) would require an investment of $10.7 billion over an estimated 15 years. That degree of development would result in estimated firm energy production of approximately 35,300 GWh/year and average energy production of approximately 60,000 GWh/year, thereby meeting all or most of the estimated 48,000 GWh/year demand of the riparian countries. With the SAPP plan in place, coordinated operation of the system of hydropower facilities can provide an additional 23 percent generation over uncoordinated (unilateral) operation. The value of cooperative generation therefore appears to be significant.

Implementation of all presently identified national irrigation projects would expand the equipped area by some 184 percent (including double cropping in some areas) for a total required investment of around $2.5 billion. However, this degree of development of the irrigation sector, without further development of hydropower, would reduce hydropower generation of firm energy by 21 percent and of average energy by nine percent. If identified irrigation projects were developed alongside current SAPP plans, the resulting reduction in generation would be about eight percent for firm energy and four percent for average energy.

Cooperative irrigation development (such as moving approximately 30,000 hectares of planned large irrigation infrastructure downstream) could increase firm energy generation by two percent, with a net present value of $140 million. But complexities associated with food security and self-sufficiency warrant closer examination of this scenario.

Other water-using projects (such as transfers out of the Basin and for other industrial uses within the Basin) would not have a significant effect on productive (economic) use of the water in the system at this time. But they might affect other sectors and topics, such as tourism and the environment, especially during periods of low flow. A more detailed study is warranted.

For the Lower Zambezi, restoration of natural flooding, for beneficial uses in the Delta, including fisheries, agriculture, environmental uses and better flood protection, could be assured by modifying reservoir operating guidelines at Cahora Bassa Dam. Depending on the natural flooding scenario selected, these changes could cause significant reduction in hydropower production (between three percent and 33 percent for the Cahora Bassa Dam and between four percent and 34 percent for the planned Mphanda Nkuwa Dam). More detailed studies are warranted.

Based on the findings for Scenario 8, which assumes full cooperation of the riparian countries, a reasonable balance between hydropower and irrigation investment could result in firm energy generation of some 30,000 GWh/year and 774,000 hectares of irrigated land. Those goals could be achieved while providing a level of flood protection and part restoration of natural floods in the Lower Zambezi.

The riparian countries together with their development partners may wish to act on the analysis presented here by pursuing several steps, described in detail at the end of volume 1:

- Explore and exploit the benefits of cooperative investments and coordinated operations;
- Strengthen the knowledge base and the regional capacity for river basin modeling and planning;
- Improve the hydrometeorological data system;
- Conduct studies on selected topics, including those mentioned above; and,
- Build institutional capacity for better management of water resources.

1.3 BASIC CHARACTERISTICS OF THE ZAMBEZI RIVER BASIN

The Zambezi River lies within the fourth-largest basin in Africa after the Congo, Nile, and Niger river basins. Covering 1.37 million km^2, the Zambezi River has its source in Zambia, 1,450 meters above sea level. The main stem then flows southwest into Angola, turns south, enters Zambia again, and passes through the Eastern Caprivi Strip in Namibia and northern Botswana. The Zambezi River then flows through Mosi-oa-Tunya (Victoria Falls), shared by Zambia and Zimbabwe, before entering Lake Kariba, which masses behind Kariba Dam, built in 1958. A short distance downstream from Kariba Dam, the Zambezi River is joined by the Kafue River, a major tributary, which rises in northern Zambia. The Kafue River flows through the Copperbelt of Zambia into the reservoir behind the Itezhi Tezhi Dam (ITT), built in 1976. From there, the Kafue River enters the Kafue Flats and then flows through a series of steep gorges, the site of the Kafue Gorge Upper (KGU) hydroelectric scheme, commissioned in 1979. Below the Kafue River confluence, the Zambezi River pools behind Cahora Bassa Dam in Mozambique, built in 1974. Some distance downstream, the Zambezi River is joined by the Shire River, which flows out of Lake Malawi/Niassa/Nyasa to the north. Lake Malawi/Niassa/Nyasa, which covers an area of 28,000 km^2, is the third-largest freshwater lake in Africa. From the confluence, the Zambezi River travels some 150 km, part of which is the Zambezi Delta, before entering the Indian Ocean.

The basin of the Zambezi River is generally described in terms of 13 subbasins representing major tributaries and segments (see map in figure 1.1).

From a continental perspective, the ZRB contains four important areas of biodiversity:

- *Lake Malawi/Niassa/Nyasa*, a region of importance to global conservation because of the evolutionary radiation of fish groups and other aquatic species.
- *The swamps, floodplains, and woodlands* of the paleo-Upper Zambezi in Zambia and northern Botswana, including the areas of Barotseland, Busanga and Kafue, which along with the Bangweulu are thought to be areas of evolutionary radiation for groups as disparate as Reduncine antelope, suffrutices, and bulbous plants.
- *The Middle Zambezi Valley in northern Zimbabwe and the Luangwa Valley in eastern Zambia*, two of the last remaining protected areas extensive enough to support large populations of large mammals.
- *The Gorongosa/Cheringoma/Zambezi Delta* area of central Mozambique, which covers an area of enormous habitat diversity not found in such close proximity elsewhere on the continent.

The hydrology of the ZRB is not uniform, with generally high rainfall in the north and lower rainfall in the south (table 1.1). In some areas in the Upper Zambezi and around Lake Malawi/Niassa/Nyasa, rainfall can be as much as 1,400 mm/year, while in the southern part of Zimbabwe it can be as little as 500 mm/year.

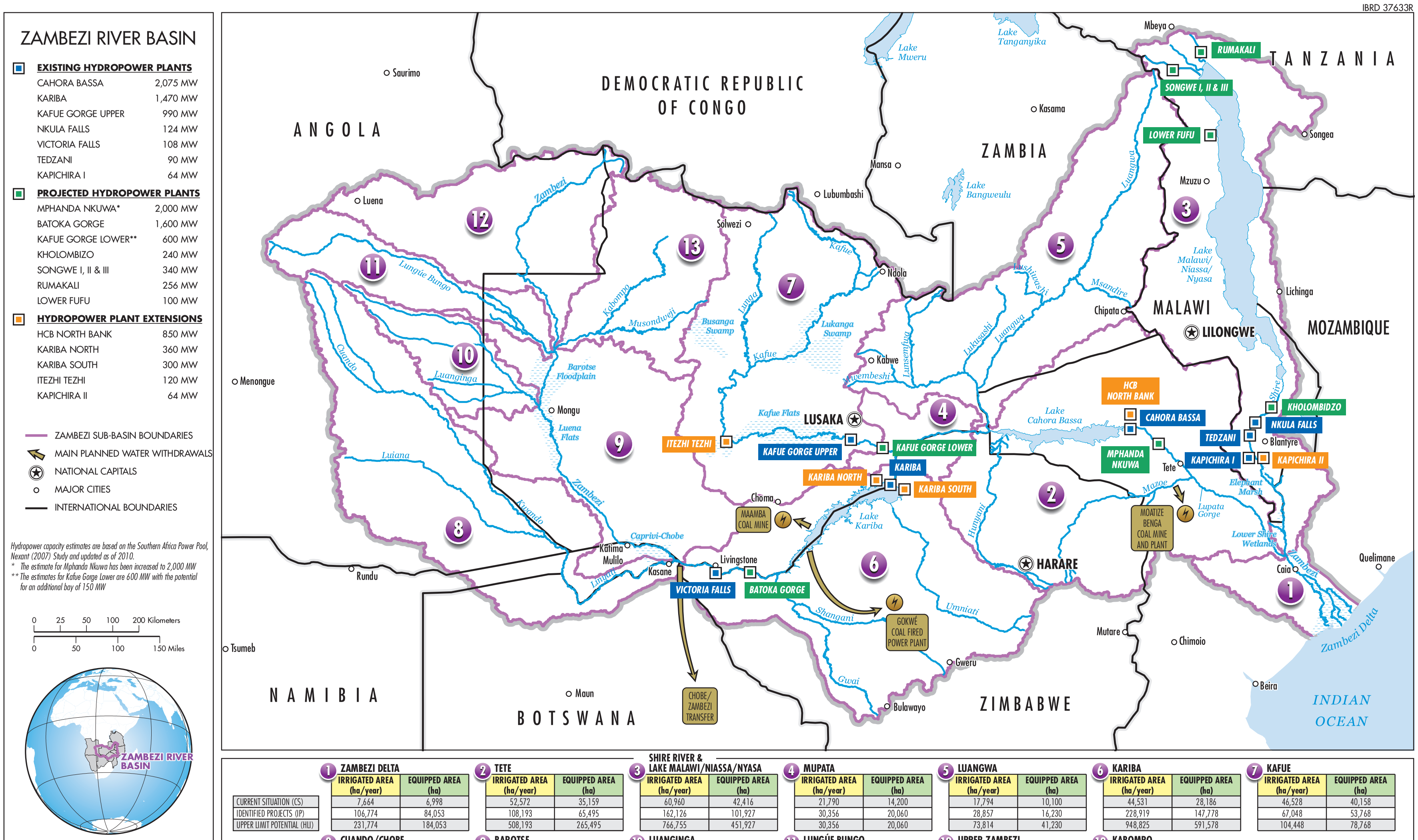
The mean annual discharge at the outlet of the Zambezi River is 4,134 m^3/s or around 130 km^3/year (figure 1.2). Due to the rainfall distribution, northern tributaries contribute much more water than southern ones. For example, the northern highlands catchment of the Upper Zambezi subbasin contributes 25 percent, Kafue River nine percent, Luangwa River 13 percent, and Shire River 12 percent—for a total of 60 percent of the Zambezi River discharge.

Table 1.1. Precipitation data for the Zambezi River Basin

Subbasin	No.	Mean annual precipitation (mm)
Kabompo	13	1,211
Upper Zambezi	12	1,225
Lungúe Bungo	11	1,103
Luanginga	10	958
Barotse	9	810
Cuando/Chobe	8	797
Kafue	7	1,042
Kariba	6	701
Luangwa	5	1,021
Mupata	4	813
Shire River and Lake Malawi/ Niassa/Nyasa	3	1,125
Tete	2	887
Zambezi Delta	1	1,060
Zambezi River Basin, mean		956

Source: Euroconsult Mott MacDonald 2007.

Figure 1.1. The Zambezi River Basin and its 13 subbasins



ZAMBEZI RIVER BASIN

🟦 **EXISTING HYDROPOWER PLANTS**

CAHORA BASSA	2,075 MW
KARIBA	1,470 MW
KAFUE GORGE UPPER	990 MW
NKULA FALLS	124 MW
VICTORIA FALLS	108 MW
TEDZANI	90 MW
KAPICHIRA I	64 MW

🟩 **PROJECTED HYDROPOWER PLANTS**

MPHANDA NKUWA*	2,000 MW
BATOKA GORGE	1,600 MW
KAFUE GORGE LOWER**	600 MW
KHOLOMBIZO	240 MW
SONGWE I, II & III	340 MW
RUMAKALI	256 MW
LOWER FUFU	100 MW

🟧 **HYDROPOWER PLANT EXTENSIONS**

HCB NORTH BANK	850 MW
KARIBA NORTH	360 MW
KARIBA SOUTH	300 MW
ITEZHI TEZHI	120 MW
KAPICHIRA II	64 MW

- ZAMBEZI SUB-BASIN BOUNDARIES
- MAIN PLANNED WATER WITHDRAWALS
- NATIONAL CAPITALS
- MAJOR CITIES
- INTERNATIONAL BOUNDARIES

Hydropower capacity estimates are based on the Southern Africa Power Pool, Nexant (2007) Study and updated as of 2010.

* *The estimate for Mphanda Nkuwa has been increased to 2,000 MW*

** *The estimates for Kafue Gorge Lower are 600 MW with the potential for an additional bay of 150 MW*

	① ZAMBEZI DELTA IRRIGATED AREA (ha/year)	① ZAMBEZI DELTA EQUIPPED AREA (ha)	② TETE IRRIGATED AREA (ha/year)	② TETE EQUIPPED AREA (ha)	③ SHIRE RIVER & LAKE MALAWI/NIASSA/NYASA IRRIGATED AREA (ha/year)	③ SHIRE RIVER & LAKE MALAWI/NIASSA/NYASA EQUIPPED AREA (ha)	④ MUPATA IRRIGATED AREA (ha/year)	④ MUPATA EQUIPPED AREA (ha)
CURRENT SITUATION (CS)	7,664	6,998	52,572	35,159	60,960	42,416	21,790	14,200
IDENTIFIED PROJECTS (IP)	106,774	84,053	108,193	65,495	162,126	101,927	30,356	20,060
UPPER LIMIT POTENTIAL (HLI)	231,774	184,053	508,193	265,495	766,755	451,927	30,356	20,060

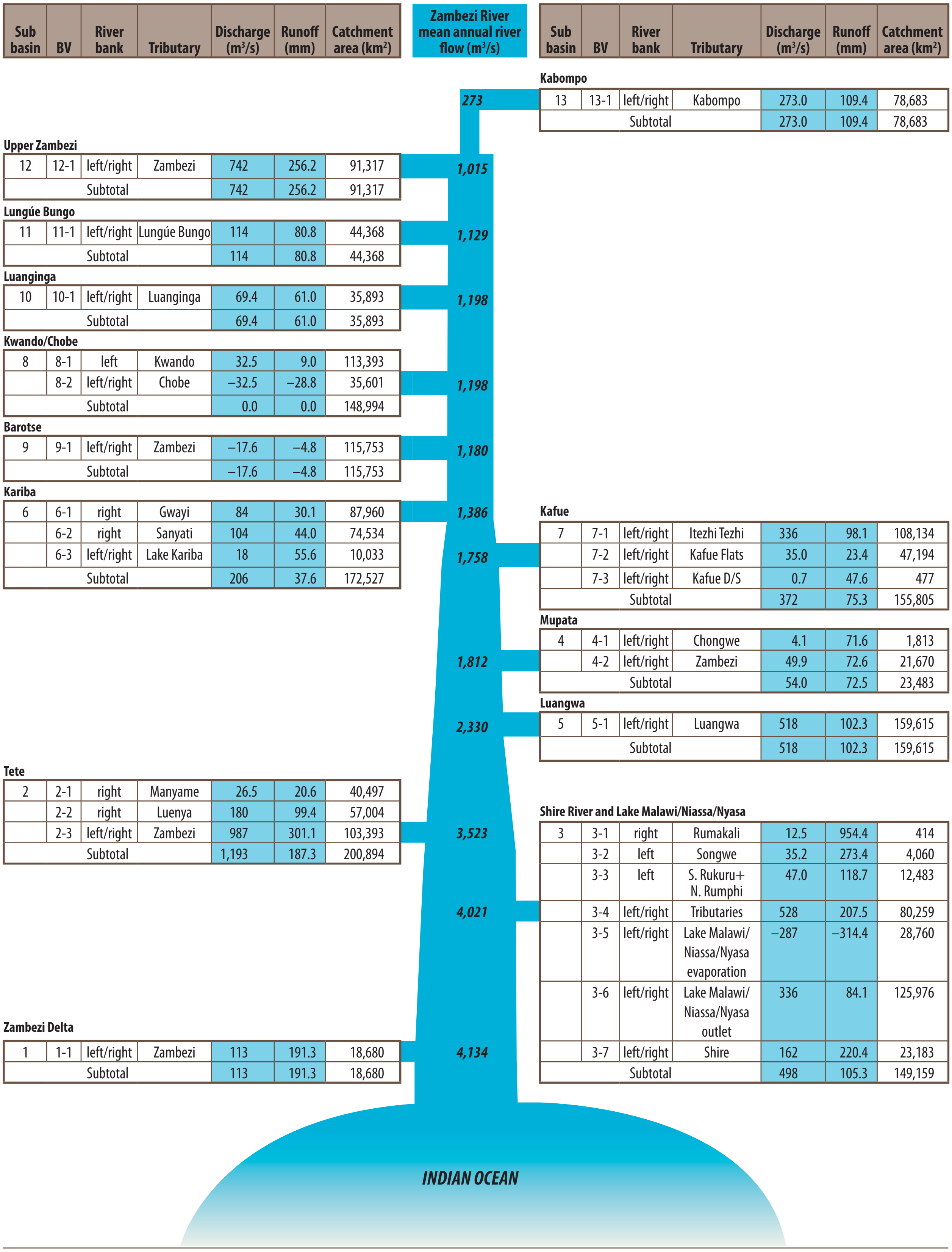
	⑤ LUANGWA IRRIGATED AREA (ha/year)	⑤ LUANGWA EQUIPPED AREA (ha)	⑥ KARIBA IRRIGATED AREA (ha/year)	⑥ KARIBA EQUIPPED AREA (ha)	⑦ KAFUE IRRIGATED AREA (ha/year)	⑦ KAFUE EQUIPPED AREA (ha)
CURRENT SITUATION (CS)	17,794	10,100	44,531	28,186	46,528	40,158
IDENTIFIED PROJECTS (IP)	28,857	16,230	228,919	147,778	67,048	53,768
UPPER LIMIT POTENTIAL (HLI)	73,814	41,230	948,825	591,578	104,448	78,768

	⑧ CUANDO/CHOBE IRRIGATED AREA (ha/year)	⑧ CUANDO/CHOBE EQUIPPED AREA (ha)	⑨ BAROTSE IRRIGATED AREA (ha/year)	⑨ BAROTSE EQUIPPED AREA (ha)	⑩ LUANGINGA IRRIGATED AREA (ha/year)	⑩ LUANGINGA EQUIPPED AREA (ha)
CURRENT SITUATION (CS)	765	620	340	200	1,000	750
IDENTIFIED PROJECTS (IP)	1,215	920	12,753	7,208	6,000	5,750
UPPER LIMIT POTENTIAL (HLI)	19,215	15,920	30,466	17,208	18,500	15,750

	⑪ LUNGÚE BUNGO IRRIGATED AREA (ha/year)	⑪ LUNGÚE BUNGO EQUIPPED AREA (ha)	⑫ UPPER ZAMBEZI IRRIGATED AREA (ha/year)	⑫ UPPER ZAMBEZI EQUIPPED AREA (ha)	⑬ KABOMPO IRRIGATED AREA (ha/year)	⑬ KABOMPO EQUIPPED AREA (ha)
CURRENT SITUATION (CS)	1,250	1,000	3,250	2,500	595	350
IDENTIFIED PROJECTS (IP)	1,875	1,500	8,250	7,500	11,314	6,650
UPPER LIMIT POTENTIAL (HLI)	14,375	11,500	20,750	17,500	28,328	16,650

NOVEMBER 2010

Figure 1.2. Schematic of the Zambezi River with deregulated mean annual discharge (m^3/s) and runoff (mm)



Kabompo

Sub basin	BV	River bank	Tributary	Discharge (m^3/s)	Runoff (mm)	Catchment area (km^2)
13	13-1	left/right	Kabompo	273.0	109.4	78,683
		Subtotal		273.0	109.4	78,683

Upper Zambezi

Sub basin	BV	River bank	Tributary	Discharge (m^3/s)	Runoff (mm)	Catchment area (km^2)
12	12-1	left/right	Zambezi	742	256.2	91,317
		Subtotal		742	256.2	91,317

Lungúe Bungo

Sub basin	BV	River bank	Tributary	Discharge (m^3/s)	Runoff (mm)	Catchment area (km^2)
11	11-1	left/right	Lungúe Bungo	114	80.8	44,368
		Subtotal		114	80.8	44,368

Luanginga

Sub basin	BV	River bank	Tributary	Discharge (m^3/s)	Runoff (mm)	Catchment area (km^2)
10	10-1	left/right	Luanginga	69.4	61.0	35,893
		Subtotal		69.4	61.0	35,893

Kwando/Chobe

Sub basin	BV	River bank	Tributary	Discharge (m^3/s)	Runoff (mm)	Catchment area (km^2)
8	8-1	left	Kwando	32.5	9.0	113,393
	8-2	left/right	Chobe	−32.5	−28.8	35,601
		Subtotal		0.0	0.0	148,994

Barotse

Sub basin	BV	River bank	Tributary	Discharge (m^3/s)	Runoff (mm)	Catchment area (km^2)
9	9-1	left/right	Zambezi	−17.6	−4.8	115,753
		Subtotal		−17.6	−4.8	115,753

Kariba

Sub basin	BV	River bank	Tributary	Discharge (m^3/s)	Runoff (mm)	Catchment area (km^2)
6	6-1	right	Gwayi	84	30.1	87,960
	6-2	right	Sanyati	104	44.0	74,534
	6-3	left/right	Lake Kariba	18	55.6	10,033
		Subtotal		206	37.6	172,527

Kafue

Sub basin	BV	River bank	Tributary	Discharge (m^3/s)	Runoff (mm)	Catchment area (km^2)
7	7-1	left/right	Itezhi Tezhi	336	98.1	108,134
	7-2	left/right	Kafue Flats	35.0	23.4	47,194
	7-3	left/right	Kafue D/S	0.7	47.6	477
		Subtotal		372	75.3	155,805

Mupata

Sub basin	BV	River bank	Tributary	Discharge (m^3/s)	Runoff (mm)	Catchment area (km^2)
4	4-1	left/right	Chongwe	4.1	71.6	1,813
	4-2	left/right	Zambezi	49.9	72.6	21,670
		Subtotal		54.0	72.5	23,483

Luangwa

Sub basin	BV	River bank	Tributary	Discharge (m^3/s)	Runoff (mm)	Catchment area (km^2)
5	5-1	left/right	Luangwa	518	102.3	159,615
		Subtotal		518	102.3	159,615

Tete

Sub basin	BV	River bank	Tributary	Discharge (m^3/s)	Runoff (mm)	Catchment area (km^2)
2	2-1	right	Manyame	26.5	20.6	40,497
	2-2	right	Luenya	180	99.4	57,004
	2-3	left/right	Zambezi	987	301.1	103,393
		Subtotal		1,193	187.3	200,894

Shire River and Lake Malawi/Niassa/Nyasa

Sub basin	BV	River bank	Tributary	Discharge (m^3/s)	Runoff (mm)	Catchment area (km^2)
3	3-1	right	Rumakali	12.5	954.4	414
	3-2	left	Songwe	35.2	273.4	4,060
	3-3	left	S. Rukuru+ N. Rumphi	47.0	118.7	12,483
	3-4	left/right	Tributaries	528	207.5	80,259
	3-5	left/right	Lake Malawi/ Niassa/Nyasa evaporation	−287	−314.4	28,760
	3-6	left/right	Lake Malawi/ Niassa/Nyasa outlet	336	84.1	125,976
	3-7	left/right	Shire	162	220.4	23,183
		Subtotal		498	105.3	149,159

Zambezi Delta

Sub basin	BV	River bank	Tributary	Discharge (m^3/s)	Runoff (mm)	Catchment area (km^2)
1	1-1	left/right	Zambezi	113	191.3	18,680
		Subtotal		113	191.3	18,680

Note: Excludes the operational influence at the Kariba, Cahora Bassa, and Itezhi Tezhi dams.

1.4 POPULATION AND ECONOMY

The population of the ZRB is approximately 30 million (table 1.2), more than 85 percent of whom live in Malawi, Zimbabwe, and Zambia within four subbasins: Kafue, Kariba, Tete, and the Shire River and Lake Malawi/Niassa/Nyasa.

Of the total population, approximately 7.6 million (25 percent) live in 21 main urban centers (with 50,000 or more inhabitants). The rest live in rural areas. The proportion of rural population varies from country to country, from over 50 percent in Zambia to around 85 percent in Malawi.

The ZRB is rich in natural resources. The main economic activities are fisheries, mining, agriculture, tourism, and manufacturing. Industries depend on the electricity produced in the hydropower plants (HPPs) of the Basin, as well as on other sources of energy (primarily coal and oil).

The eight riparian countries of the Basin represent a wide range of economic conditions. Annual gross domestic product per capita ranges from $122 in Zimbabwe to more than $7,000 in Botswana. Angola, Botswana, and Namibia have healthy current account surpluses, chiefly due to their oil and diamond resources (table 1.3).

1.5 APPROACH AND METHODOLOGY

Water resources development is not an end in itself. Rather, it is a means to an end: the sustainable use of water for productive purposes to enhance growth and reduce poverty. The analysis reported here was undertaken from an economic perspective so as to better integrate the implications of the development of investment in water management infrastructure into the broad economic development and growth

Table 1.2. Population of the Zambezi River Basin
(in thousands, 2005–06 data)

Subbasin	Angola	Botswana	Malawi	Mozambique	Namibia	Tanzania	Zambia	Zimbabwe	Total	%
Kabompo (13)	4	—	—	—	—	—	279	—	283	0.9
Upper Zambezi (12)	200	—	—	—	—	—	71	—	271	0.9
Lungúe Bungo (11)	99	—	—	—	—	—	43	—	142	0.5
Luanginga (10)	66	—	—	—	—	—	56	—	122	0.4
Barotse (9)	7	—	—	—	66	—	679	—	752	2.5
Cuando/Chobe (8)	156	16	—	—	46	—	70	—	288	1
Kafue (7)	—	—	—	—	—	—	3,852	—	3,852	12.9
Kariba (6)	—	—	—	—	—	—	406	4,481	4,887	16.3
Luangwa (5)	—	—	40	12	—	—	1,765	—	1,817	6.1
Mupata (4)	—	—	—	—	—	—	113	111	224	0.7
Shire River - Lake Malawi/Niassa/ Nyasa (3)	—	—	10,059	614	—	1,240	13	—	11,926	39.8
Tete (2)	—	—	182	1,641	—	—	221	3,011	5,055	16.9
Zambezi Delta (1)	—	—	—	349	—	—	—	—	349	1.2
Total	**532**	**17**	**10,281**	**2,616**	**112**	**1,240**	**7,568**	**7,603**	**29,969**	**—**
%	1.8	0.1	34.3	8.7	0.4	4.1	25.3	25.4	—	100

Source: Euroconsult Mott MacDonald 2007; SEDAC 2008.

Table 1.3. Macroeconomic data by country (2006)

Country	Population (million)	GDP (US$ million)	GDP/cap (US$)	Inflation rate (%)
Angola	15.8	45.2	2,847	12.2
Botswana	1.6	11.1	7,019	7.1
Malawi	13.1	3.2	241	8.1
Mozambique	20.0	6.8	338	7.9
Namibia	2.0	6.9	3,389	6.7
Tanzania	38.2	14.2	372	7.0
Zambia	11.9	10.9	917	10.7
Zimbabwe	11.7	1.4	122	>10,000

Source: Euroconsult Mott MacDonald 2007; SEDAC 2008.

objectives of the riparian countries and the Basin as a whole. An international river system such as the ZRB is extremely complex. That complexity is reflected in, but also compounded by, the large number of initiatives being undertaken within the Basin and by the large volume of data and information that already exists. To analyze such a complex system, simplifications and assumptions are unavoidable. Those assumptions and their potential implications are acknowledged throughout the report.

1.5.1 Analytical framework

Operating within the framework of integrated water resources management, this analysis considers the following water users as stakeholders: irrigated agriculture, hydropower, municipal development, rural development, navigation, tourism and wildlife conservation, and the environment. The analytical framework considered here is illustrated graphically in figure 1.3. The present context of the natural and developed resource base, as well as cross-cutting factors, of the ZRB (rows in the matrix) is assessed against the water-using stakeholders (columns in the matrix) for a set of development scenarios. Those development scenarios are focused on two key water-using stakeholders that require major investments in the region: hydropower and irrigated agriculture.

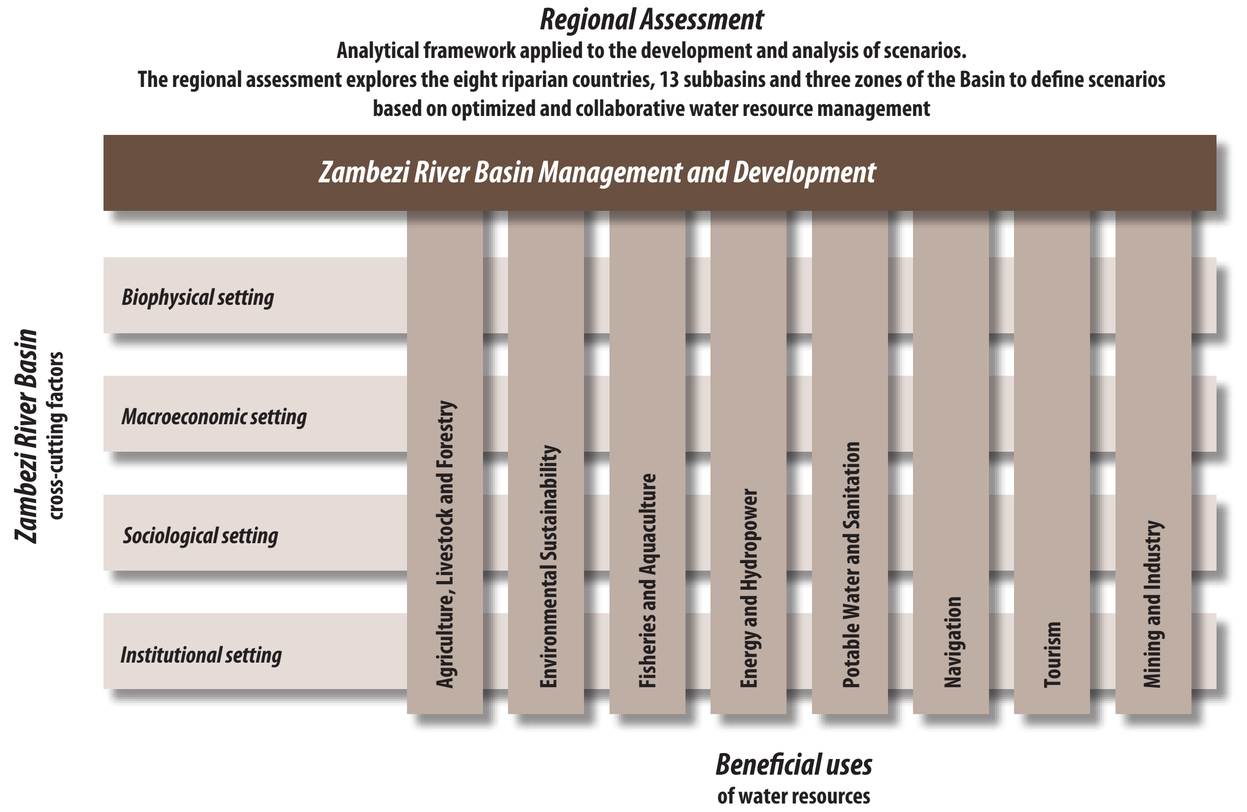
While the need to consider the details of the interaction among all stakeholders is acknowledged, the focus of this analysis is on major water-related investments being considered by the riparian countries in their national development plans. Development scenarios for other stakeholders can be superimposed on this analysis at a later time. For the time being, however, water supply and sanitation, as well as environmental imperatives, are considered as givens in nearly all scenarios considered. In other words, hydropower and irrigation development are superimposed over the continued provision of water for basic human needs and environmental sustainability. This approach differs from the conventional one of assuming basic water needs and environmental sustainability as constraints on the optimized use of water.

It should be noted that the scenarios for full basin-wide hydropower potential and full irrigation development are primarily of analytical interest, rather than for practical application. They are used here to help bracket the range and scope of the analysis and to provide reference points. The scenarios are based on identified projects in national and regional plans, and are dependent on enabling political and economic preconditions for their full implementation. The full potential for hydropower and irrigation in the Basin is not expected to be achieved in the time horizon of this analysis, which is based on the current national economic plans of the riparian countries.

The scenario analysis is carried out for the primary objective of determining and maximizing economic benefits while meeting water supply and environmental sustainability requirements. Full cooperation among the riparian countries is assumed. The scenarios are tested using a coupled hydro-economic modeling system described in volume 4. The purpose of the modeling effort is to provide insight into the range of gains that may be expected from various infrastructure investments along the axes of full hydropower and irrigation development (while continuing to satisfy requirements for water supply and environmental sustainability).

Additionally, the analysis examines the effects of conjunctive or coordinated operation of existing facilities, as well as potential gains from the strategic development of new facilities. The analysis also addresses the potential impact of the development scenarios on the environment (wetlands), tourism,

Figure 1.3. Zambezi River Basin: scenario analysis matrix



flood control, guaranteed minimum river flows in the dry season, and other topics.

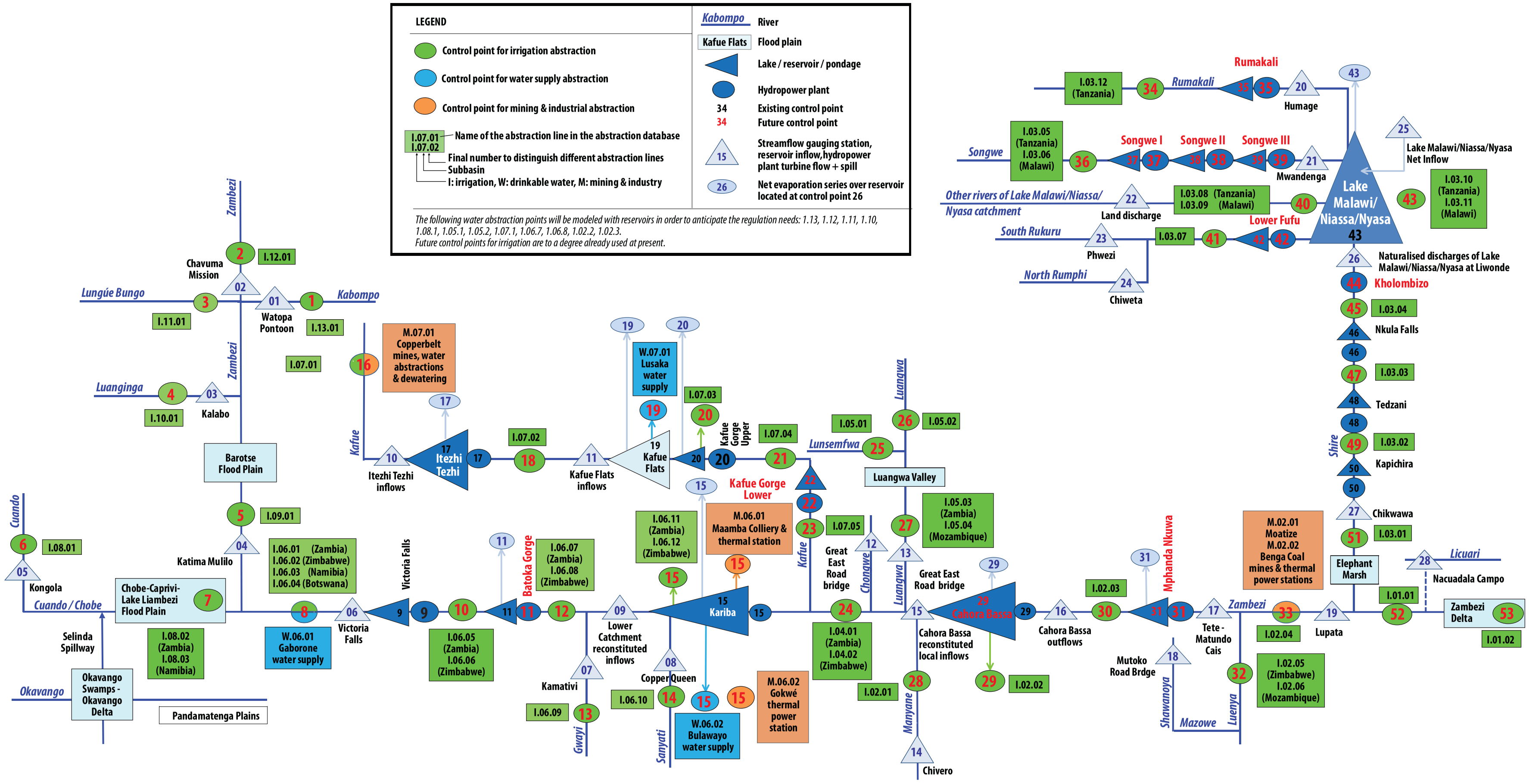
Specific attention is also given to the operational and investment options for reducing flood risks downstream of Cahora Bassa Dam and to the possibility of partial restoration of natural floods to manage the impact on the Zambezi Delta of existing dams on the Zambezi River. In this analysis, the impact of climate change on the hydrology of the ZRB and on the investment options assessed are addressed through a rudimentary incremental variation of key driving factors. Climate change is deemed a risk factor to developments and more detailed analysis is warranted for an in-depth understanding of impact. The ongoing efforts by the riparian countries and the development partners on assessing the impact of climate change on the Zambezi River Basin will provide guidance in due course.

Looming large in the analysis are the economics of different options, conceived in terms of the effect of potential investments on national and regional growth and on poverty reduction. With that in mind, the analysis considers the entire Basin as a single natural resource base while examining potential sectoral investments. This approach is appropriate for initial indicative purposes and provides a common point of reference for all riparian countries. The complexities inherent in national economics and transboundary political relationships are not directly addressed in this analysis. This is left to the riparian countries to address, informed by the results of this and other analyses.

1.5.2 The River/Reservoir System Model

The modeling package adopted for the analysis is HEC-3, a river and reservoir system model developed by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers. The version of the model used in this study, illustrated in figure 1.4, was modified by the consultants to improve some of its features. The same software package was

Figure 1.4. Schematic of the river/reservoir system model for the Zambezi River Basin



The following water abstraction points will be modeled with reservoirs in order to anticipate the regulation needs: 1.13, 1.12, 1.11, 1.10, 1.08.1, 1.05.1, 1.05.2, 1.07.1, 1.06.7, 1.06.8, 1.02.2, 1.02.3.
Future control points for irrigation are to a degree already used at present.

adopted during the SADC 3.0.4 project that investigated joint operation of the Kariba, Kafue Gorge Upper, and Cahora Bassa dams. The model is still being used by the Zambezi River Authority (ZRA). The fact that water professionals in the ZRB were familiar with the earlier version of the model partly accounts for its selection. A detailed description of the model appears in volume 4 of this report.

In the present analysis, the modeling time step adopted is one month. All inputs, inflows, evaporation, diversions or withdrawals, downstream flow demands, and reservoir rule curves are on a monthly basis. The outputs of the model—reservoir storage and outflows, turbine flow, spill, and power generation—are also on a monthly basis. The simulation period spans 40 years—from October 1962 to September 2002—long enough to obtain a realistic estimate of energy production. The main inflow series, from the Zambezi River at Victoria Falls, shows that the flow sequence from 1962 to 1981 is above normal, while the sequence from 1982 to 2002 is below normal. The flow data available to the study team were insufficient to consider extending the simulation period beyond 2002. Information on groundwater (e.g., status of aquifers and abstraction levels) was too insufficient to allow for sufficient conjunctive analysis.

While the focus of this analysis is on hydropower and irrigation, the river/reservoir system model takes into account all sectors concerned with water management, notably tourism, fisheries, environment such as environmental flows (e-flows) and specific important wetlands, flood control, and industry. Details of the guidelines and rule curves used in the model for reservoir operations, flood management, delta and wetlands management, environmental flows, tourism flows, and fisheries flows are given in volume 4 of this series.

Maintaining e-flows throughout the system was a major consideration in this analysis. Reaches of the Zambezi River upstream of the Kariba and Cahora Bassa dams are generally considered in near-pristine condition. The tributaries rising in Zimbabwe are highly developed, with river-regulation infrastructure for irrigation. The Kafue River is also regulated and sustains a large number of water-using sectors. The Zambezi River downstream from the Kariba and Cahora Bassa dams, like the Zambezi Delta, has been permanently altered by river-regulation infrastructure.

To take into account e-flows in the various reaches of the Zambezi River, some assumptions had to be made related to the amount of water available at all times. The following e-flow criteria were used in the river/reservoir system model in almost all the scenarios: the flow should never fall below historical low-flow levels in dry years of the record,[1] where records are available. Moreover, the average annual flow cannot fall below 60 percent of the natural average annual flow downstream from Kariba Dam. The minimum flow in the Zambezi Delta in February was set at 7,000 m^3/s for at least four out of five dry years.

The development scenarios, the state of the basin, and the modeling, analysis, and input data are described in detail in volumes 2, 3, and 4, respectively. Together, they strengthen the analytical knowledge base available for making informed decisions about investment opportunities, financing, and benefit sharing. Moreover, the analysis can assist the Zambezi River Watercourse Commission awaiting ratification (ZAMCOM), SADC, and riparian countries by providing insight into options for joint or cooperative development as well as associated benefit sharing.

1.5.3 The Economic Assessment Tool

The economic assessment approach used here incorporates the inputs from the various projects for sector analysis to provide an overall analysis of the economic implications of development and investment scenarios. A schematic of the elements of the development scenario is given in figure 1.5. The development scenarios were compared to assess the relative viability of a given option. For hydropower and irrigation, the basic elements of the analysis are the projects identified by the riparian countries. This analysis is multi-sectoral by design; the major link among the sectors (and associated projects) is the allocation or use of water.

The economic analysis uses input from the river/reservoir system model.

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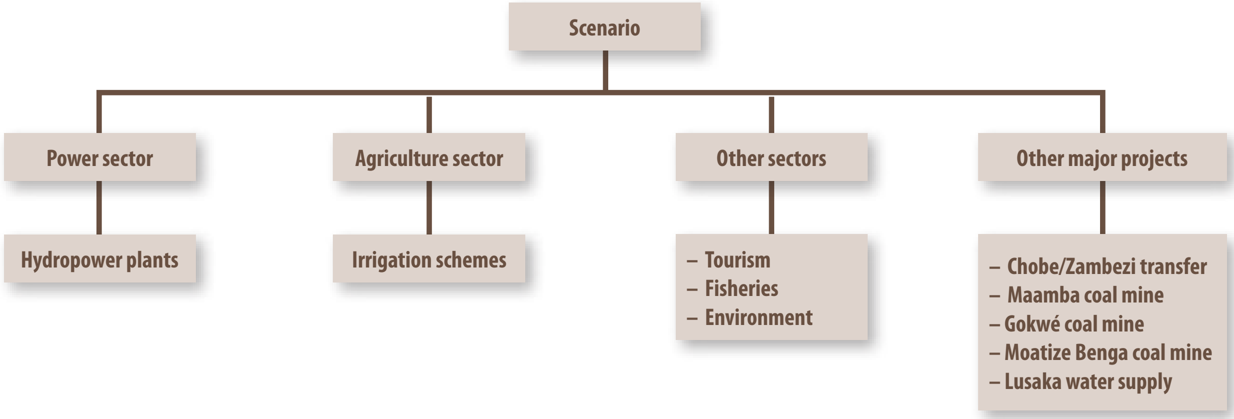
[1] The statistical dry year considered here is the natural flow with a five-year return period.

Figure 1.5. Schematic of the elements of the economic analysis tool



- *Hydropower.* The model uses the production figures from the hydropower installations (described in detail in the section on the hydropower in volume 3) and attributes these to the various hydropower projects.
- *Irrigation.* Based on the allocated water and development scenarios, the appropriate models for the relevant irrigation projects are used at specific abstraction points in the river/reservoir system model, and the associated costs and benefits are calculated.
- *Other sectors.* Data on flows at Victoria Falls is used to assess their impact on tourism. Financial and economic values of different flood management options and their impact on the Zambezi Delta are calculated. The value of wetlands used in the analysis tool is derived from the analysis of the environmental resources (details are provided in volume 3).
- *Other major projects.* Water-transfer schemes associated with these major projects are included in the scenario analysis.

The economic assessment is based on a number of assumptions regarding its parameters. It includes the following:

- *Scenario level* – starting date, time horizon;
- *Sector* – sector-specific parameters and prices, the specific irrigation models used in sector projects (e.g., crop budgets); and
- *Project* – project time frames, project-specific costs and benefits.

Details of the economic analysis assumptions can be found in volume 4.

The economic assessment tool provides, as output, a summary table, which includes:

- Hydropower generation and agriculture output, presented in the agricultural and irrigation calculations;
- Cash flows based on project cash flows;
- Economic internal rate of return and net present value (NPV) by development scenario, based on the appropriate time frame and project implementation schedule;
- Employment impact (jobs) calculated as the ratio of jobs to gigawatt hours of installed capacity or jobs to hectares of a particular crop; and,
- A sensitivity analysis that was carried out for variations in investment costs, prices, and production values.

2

Biophysical and Socioeconomic Context

The Zambezi River Basin (ZRB) is made up of 13 major subbasins with the river's major tributaries and catchments. These subbasins provide the scale for much of the Zambezi River Multi-Sector Investment Opportunities Analysis (MSIOA), as well as the focus of previous literature on the Zambezi River.

The ZRB is located in southern Africa between nine and 20 degrees south and between 18 and 36 degrees east. The Basin is the fourth-largest in Africa after the Congo, Nile, and Niger river basins. It has an area of 137 million hectares (1.37 million km^2) and extends into Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia, and Zimbabwe. The ZRB covers almost all of the territory of Malawi, more than 70 percent of Zambia, and almost half of Zimbabwe. Significant portions of Mozambique and Angola also fall within the Basin, as well as smaller portions of Tanzania, Botswana, and Namibia.

Most of the ZRB is situated on the high plateau of the ancient continent of Gondwana, with elevations between 800 and 1,450 meters above sea level. The majority of the Basin's area is situated between 1,000 and 1,300 meters, with only a small portion below 100 meters or above 1,500 meters.

2.1 OVERVIEW OF BASIN HYDROLOGY

2.1.1 Rainfall characteristics

Rainfall varies throughout the ZRB (table 2.1). It is generally higher in the northern parts and reaches up to 1,400 mm per year in the upper reaches and around Lake Malawi/Niassa/Nyasa. It is lowest in the southern parts—such as the area within Zimbabwe—with a maximum of 500 mm per year.

2.1.2 Runoff characteristics

Hydrological time series are needed to identify investment opportunities relevant to the major water-using sectors of the ZRB. Ideally for the study period (October 1962 to September 2002), the series should

Table 2.1. Rainfall in the Zambezi River Basin

Subbasin		Mean annual precipitation (mm)
Name	**Number**	
Kabompo	13	1,211
Upper Zambezi	12	1,225
Lungúe Bungo	11	1,103
Luanginga	10	958
Barotse	9	810
Cuando/Chobe	8	797
Kafue	7	1,042
Kariba	6	701
Luangwa	5	1,021
Mupata	4	813
Shire River and Lake Malawi/ Niassa/Nyasa	3	1,125
Tete	2	887
Zambezi Delta	1	1,060
Total		**956**

Source: Euroconsult Mott MacDonald 2007.

provide information on the variability of flow both throughout a given year and over the longer term. Monthly hydrological time series that cover at least a full drought period are the minimum requirement for the analysis and thus for the viability of any proposed project.

Mean average runoff data from the ZRB are published in several reports and for the purposes of this study were initially obtained from the Rapid Assessment Report (Euroconsult Mott MacDonald 2007). Time series could not be obtained, however, and the average runoff data appear to be based on long-term averages that do not extend past a drought period.

Monthly historical flows at hydrometric stations and hydropower plants were obtained mainly from the Zambezi Water Information System (ZAMWIS) database, developed during the Zambezi Action Plan Project 6, Phase II (ZACPRO 6.2). Other sources, including water departments of some of the riparian countries and power utilities, also provided flow data. Runoff is based on recorded flows and time series. Missing flows were estimated by cross-correlation with the flows of neighboring hydrometric stations to cover over the whole study period. The simulation could not be extended beyond 2002 due to insufficient flow data. In the case of large reservoirs (Kariba and Cahora Bassa), the unregulated inflows were estimated using the principle of continuity—that is, based on changes

Table 2.2. Runoff from the Zambezi River Basin

Subbasin		Area (km^2)		Mean annual runoff (km^3)	
Name	**Number**	**Incremental**	**Total**	**Incremental**	**Total**
Kabompo	13	78,683	78,683	8.61	—
Upper Zambezi	12	91,317	91,317	23.40	—
Lungúe Bungo	11	44,368	44,368	3.59	—
Luanginga	10	35,893	35,893	2.19	—
Barotse	9	115,753	366,014	–0.56	37.22
Cuando/Chobe	8	148,994	148,994	0.00	—
Kafue	7	155,805	155,805	11.74	11.74
Kariba	6	172,527	687,535	6.49	43.71
Mupata	5	23,483	1,026,438	1.68	73.46
Luangwa	4	159,615	159,615	16.33	16.32
Shire River – Lake Malawi/Niassa/Nyasa	3	149,159	149,159	15.71	—
Tete	2	200,894	1,227,332	37.64	111.10
Zambezi Delta	1	18,680	1,395,171	3.58	130.39
Total		**1,395,171**		**130.39**	

in reservoir storage, outflows through the turbines and spillway gates, and reservoir evaporation. The main inflow series at Victoria Falls show that the flow sequence from 1962 to 1981 was above normal, while the sequence from 1982 to 2002 was below normal. Reservoir evaporation estimates are further detailed in volume 4.

While assembling the time series, the boundaries of subbasin catchments appeared to differ from earlier research. Certain flow patterns may never be concretely determined in many cases, especially in places such as the Okavango Delta and the Zambezi River Delta, which explains the differences encountered.

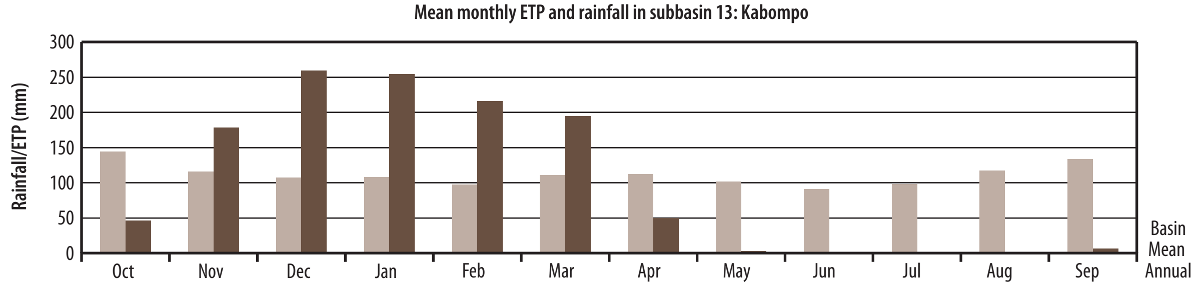
2.1.3 Subbasin characteristics

The following subsections summarize the general surface water characteristics of each of the 13 subbasins considered in the study. Hydrographs for each subbasin indicate present average rainfall patterns, evapotranspiration rates, net rainfall amounts, and driest year on record (most subbasins experienced serious drought in 1991–92).

Kabompo (subbasin 13)

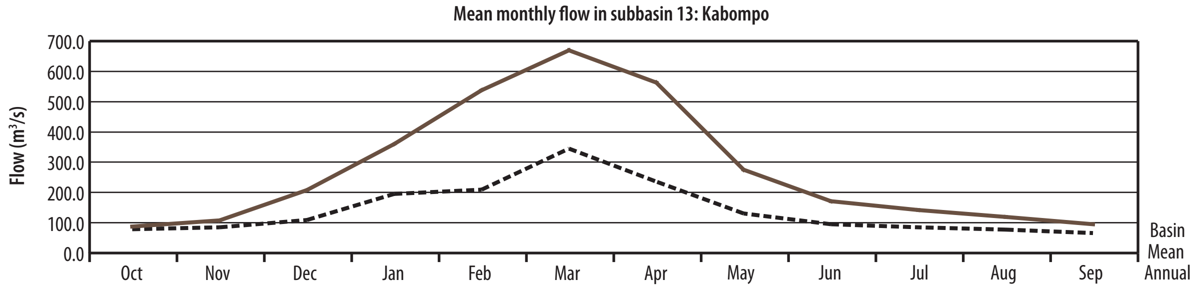
The Kabompo subbasin is located almost entirely within Zambia, within the high rainfall (figure 2.1.) zone in the Upper ZRB. Rainfall is estimated to be 1,200 mm per year on average. The annual average runoff volume is approximately 8,615 km^3. Monthly runoff is lowest between September and November, dipping to as low as 130 km^3 in October. The Kabompo subbasin is a headwater catchment with floods occurring shortly after heavy rainfall. Floods occur primarily during February and March. The highest recorded runoff volume is 3,425 km^3 during April. Water withdrawals for irrigation are limited and estimated at an annual 4.8 km^3. There are no dams in the subbasin, although there are formal plans for their construction.

Figure 2.1. Hydrograph of Kabompo, subbasin 13 (rainfall, ETP and flow)



Mean monthly ETP and rainfall in subbasin 13: Kabompo

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
■ ETP	144	116	107	108	97	111	112	102	91	98	117	134	1,337
■ Rain	46	178	259	254	216	195	50	3	1	0	1	6	1,209



Mean monthly flow in subbasin 13: Kabompo

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
- - Drought	73.4	80.5	104.2	190.6	204.8	339.8	230.9	125.5	90.0	80.5	72.2	60.4	137.7
— Average	82.0	102.8	203.3	354.5	532.9	664.6	558.4	270.0	166.7	137.3	113.8	89.8	273.0

Upper Zambezi (subbasin 12)

High rainfall in the Upper Zambezi subbasin leads to heavy runoff. The average total runoff volume is 23,411 km^3 per year (figure 2.2.). During drier years, runoff may be closer to 8,000 km^3. The lowest yearly volume on record is 56 km^3. Similar to the Kabompo, the Upper Zambezi experiences floods shortly after heavy rainfall. The highest runoff volume is usually recorded in April, often reaching more than 14,056 km^3. A small amount of water (3.6 km^3) is withdrawn for irrigation and run-of-the-river (R-o-R) in Angola. The subbasin has no dams or hydropower constructions, but there are plans for very small hydropower plants; the largest has a proposed installed capacity of 11 megawatts (MW).

Lungúe Bungo (subbasin 11)

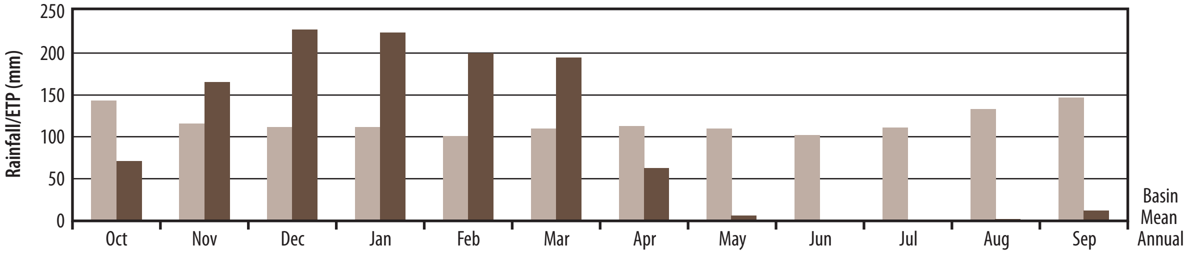
Despite high rainfall, the Lungúe Bungo subbasin has limited runoff compared with that of upstream subbasins (figure 2.3.). The subbasin is a headwater catchment and floods shortly after heavy rainfall. The highest monthly runoff volume, estimated to be 3,725 km^3, is recorded in March. The average total runoff volume is estimated to be 2,587 km^3 per year and 754 km^3 in drier years. The Lungúe Bungo has the lowest withdrawals for irrigation, at less than 3.7 km^3 per year. The subbasin does not have dams or hydropower plants, and there are no formal plans for their construction.

Luanginga (subbasin 10)

The Luanginga subbasin is one of the smaller catchments in the Basin. Runoff averages 2,190 km^3 per year (figure 2.4.). Its small areal size contributes to flooding shortly after heavy rainfall. The highest monthly rainfall volume is an estimated 2,273 km^3 in March. Luanginga lies almost entirely within Angola. Like the upstream subbasins, withdrawal for irrigation is low (4.7 km^3 per year) in the subbasin. There are no dams, hydropower plants, or plans for any.

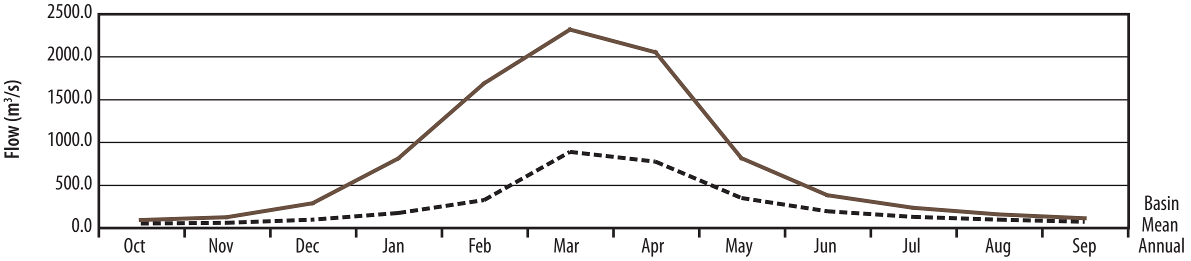
Figure 2.2. Hydrograph of Upper Zambezi, subbasin 12 (rainfall, ETP and flow)

Mean monthly ETP and rainfall in subbasin 12: Upper Zambezi



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
■ **ETP**	143	116	112	112	101	110	113	110	102	111	133	147	1,410
■ **Rain**	71	165	228	224	200	195	63	5	1	0	1	12	1,165

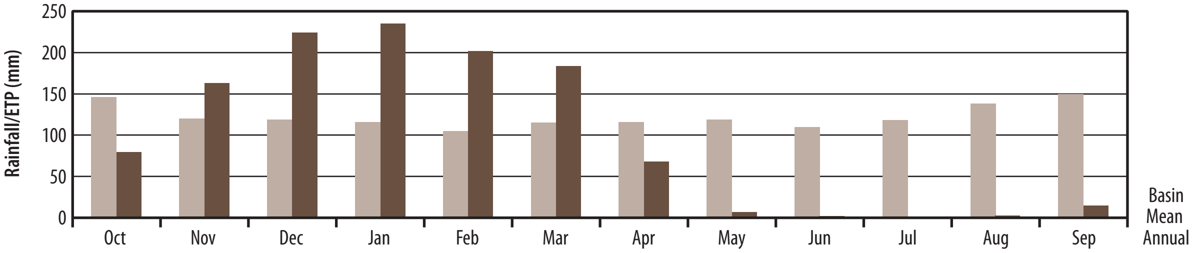
Mean monthly flow in subbasin 12: Upper Zambezi



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
- - **Drought**	37.3	43.3	80.5	157.5	310.1	873.9	758.5	333.0	180.3	113.0	80.5	55.3	251.9
— **Average**	79.5	110.5	274.6	795.3	1,674.0	2,304.1	2,037.0	799.3	366.2	221.6	144.0	96.3	741.9

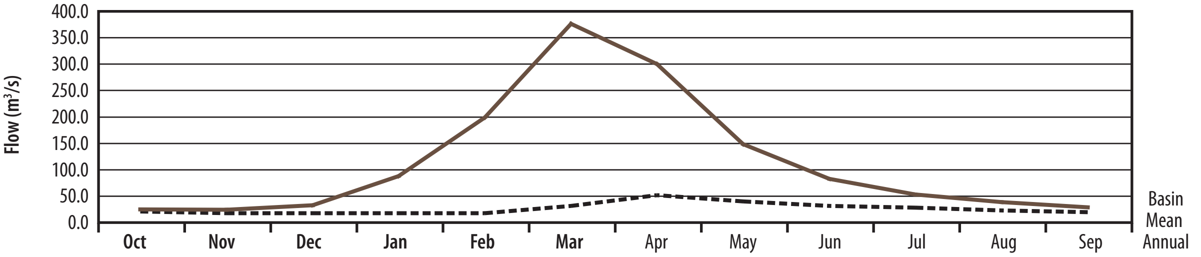
Figure 2.3. Hydrograph of Lungúe Bungo, subbasin 11 (rainfall, ETP and flow)

Mean monthly ETP and rainfall in subbasin 11: Lungúe Bungo



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
▩ **ETP**	146	120	119	116	105	115	116	119	110	118	138	150	1,472
■ **Rain**	80	163	224	235	202	184	68	7	1	0	2	15	1,181

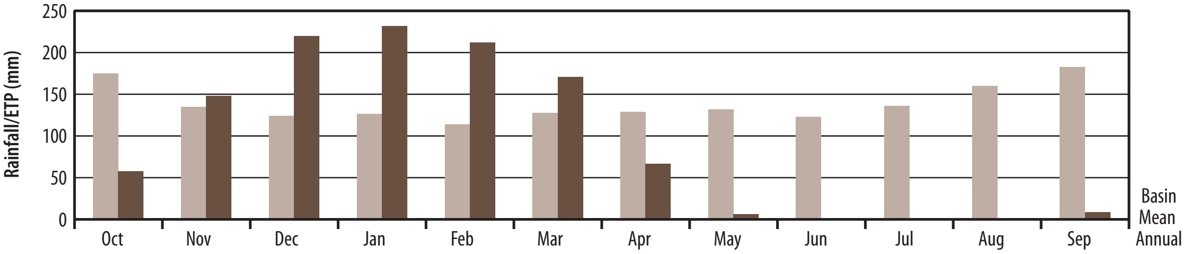
Mean monthly flow in subbasin 11: Lungúe Bungo



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
-- **Drought**	18.7	15.3	15.3	15.3	15.3	28.9	49.3	37.4	28.9	25.5	20.4	17.0	23.9
— **Average**	22.1	21.9	29.9	85.2	196.1	373.4	297.7	145.5	80.3	50.5	35.9	26.6	113.8

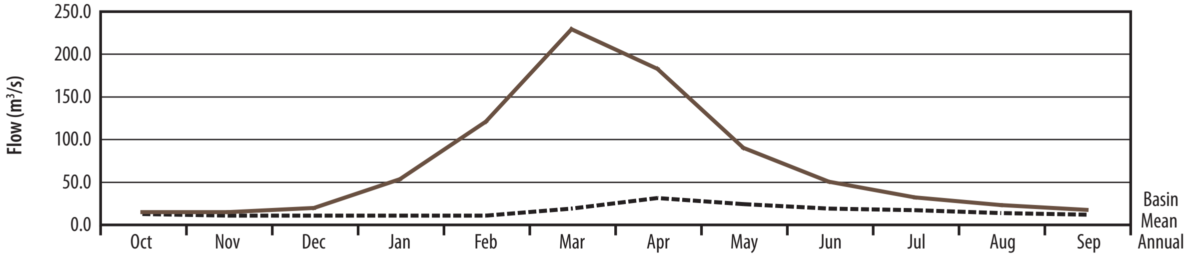
Figure 2.4. Hydrograph of Luanginga, subbasin 10 (rainfall, ETP and flow)

Mean monthly ETP and rainfall in subbasin 10: Luanginga



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
▩ **ETP**	175	135	124	127	114	128	129	132	123	136	160	183	1,666
■ **Rain**	58	148	220	232	212	171	67	6	1	0	1	9	1,125

Mean monthly flow in subbasin 10: Luanginga



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
-- **Drought**	11.4	9.3	9.3	9.3	9.3	17.6	30.1	22.8	17.6	15.6	12.4	10.4	14.6
— **Average**	13.5	13.3	18.3	52.0	119.6	227.7	181.6	88.7	49.0	30.8	21.9	16.2	69.4

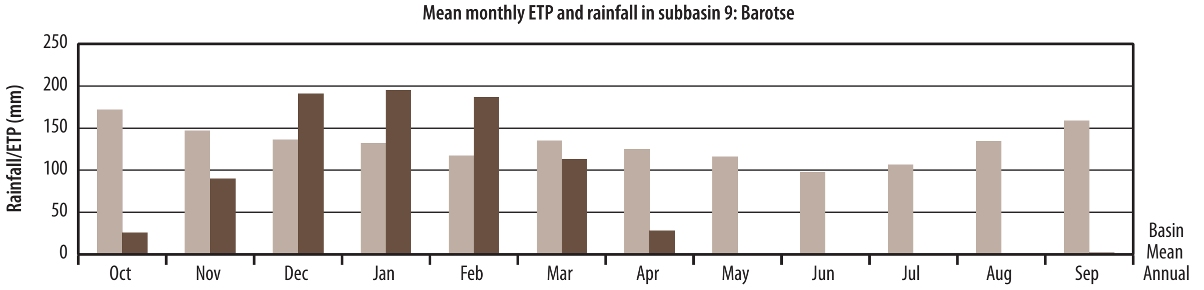
Barotse (subbasin 9)

Previous research indicated that incremental inflow from the Barotse catchment has contributed substantially to the water balance in the ZRB (figure 2.5.). More detailed analysis, however, reveals that a large wetland—the Barotse Dambo (floodplain)—attenuates the flow, leading to high rates of evaporation. The catchment therefore generates a net loss for the Basin. The Barotse subbasin's flow is cumulative. Flows from the upstream subbasin average 37,249 km^3 per year at its outlet. Peak flow is estimated to be 19,056 km^3. There is a lag time of around three months between peak rainfall and peak runoff (compared with one month in upstream subbasins). Water withdrawals for irrigation are low (3.5 km^3 per year), and irrigation potential is limited. Expansion is not expected. Recession irrigation is widely practiced; crops are planted in the moist soils of receding wetlands and emerge at the onset of the dry season. There are no dams or hydropower plants in the Barotse subbasin and no plans for any.

Cuando/Chobe (subbasin 8)

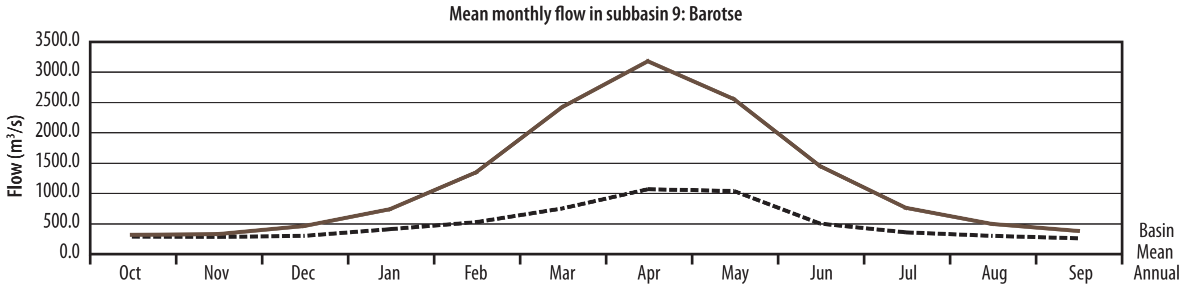
The Cuando/Chobe subbasin is the driest catchment in the ZRB. Previous research estimated runoff to be 1,100 km^3 per year—only one percent of the Basin's total runoff (figure 2.6.). The subbasin's contribution has therefore been omitted from the mass balance calculations for the ZRB. But although its contribution is thought to be negligible, the Cuando/Chobe directly affects the overall water balance in several ways. When the flow at Katima Mulilo exceeds 1,350 km^3 per second, the river overflows through an ephemeral channel into Lake Liambezi, an ephemeral lake where water evaporates. Sometimes the Chobe tributary flows into the Zambezi River and at other times the Zambezi reverses into the Chobe tributary. The direction of flow depends on a water surface differential between the two water courses at their confluence. In the past, water has also flowed from the Okavango Swamps into the ZRB through the Selinda natural spillway. Because of the geological uplift of the spillway however, this

Figure 2.5. Hydrograph of Barotse, subbasin 9 (rainfall, ETP and flow)



Mean monthly ETP and rainfall in subbasin 9: Barotse

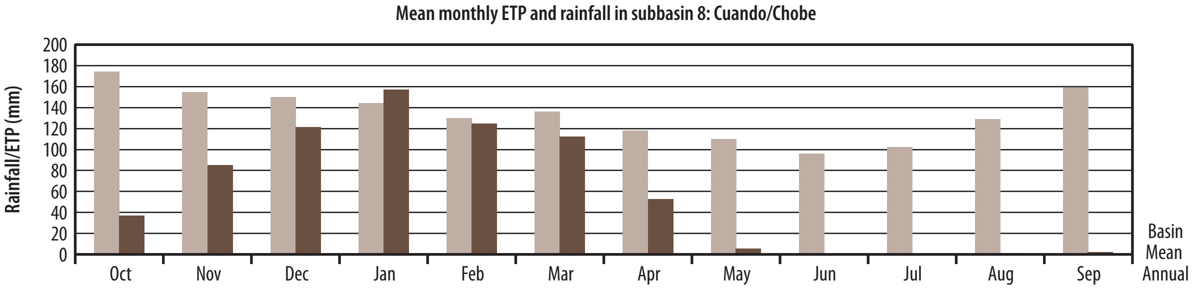
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
■ ETP	172	147	136	132	117	135	125	116	98	107	134	159	1,578
■ Rain	26	90	191	195	187	113	28	2	1	0	0	2	835



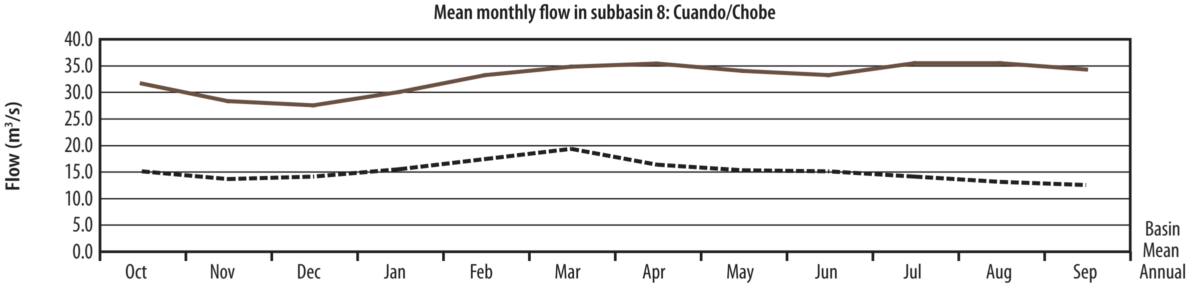
Mean monthly flow in subbasin 9: Barotse

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
- - Drought	266.6	259.2	275.3	389.6	500.6	730.5	1,047.9	1,018.0	480.7	333.5	274.8	237.1	484.5
— Average	294.2	304.1	437.6	715.0	1,324.8	2,398.4	3,157.3	2,534.5	1,427.6	738.2	474.7	357.8	1,180.3

Figure 2.6. Hydrograph of Cuando/Chobe, subbasin 8 (rainfall, ETP and flow)



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
ETP	174	155	150	144	130	136	118	110	96	102	129	159	1,603
Rain	37	85	121	157	125	112	53	5	0	0	1	2	698



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
Drought	14.9	13.4	13.9	15.3	17.2	19.1	16.1	15.1	14.9	13.9	12.9	12.3	14.9
Average	31.4	28.1	27.3	29.8	33.0	34.6	35.1	33.8	33.0	35.3	35.3	34.0	32.5

has not happened for many years. Withdrawal for irrigation, though significant, is still small compared with other parts of the Basin (8.5 km^3 per year). There are no dams or hydropower plants or plans for any.

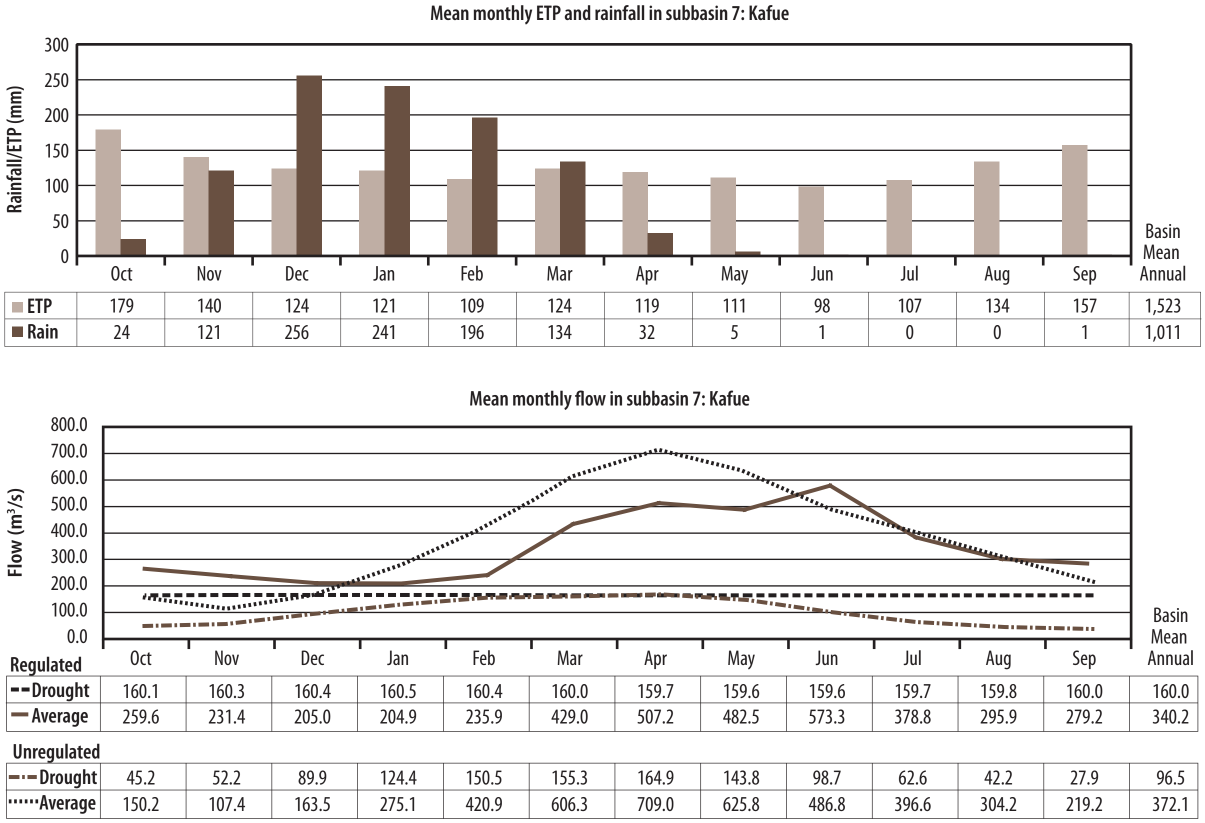
Kafue (subbasin 7)

The Kafue subbasin is a headwater catchment located entirely within Zambia. Rainfall and runoff are comparatively high, averaging 1,050 millimeters and 12,913 km^3 per year, respectively (figure 2.7.). The highest flows usually occur in March and are estimated to be 9,715 km^3. During the worst drought on record, runoff volume was only 3,266 km^3 per year. Withdrawal and demand for irrigation water is estimated to be 536 km^3 per year—among the highest totals in the ZRB. There is potential for further expansion of irrigation. Furthermore, a substantial amount of hydropower is generated in the Kafue subbasin. The Kafue Gorge Upper (KGU) hydropower station is located in the Kafue Gorge. Because storage is limited, however, releases from the upstream Itezhi Tezhi Dam (ITT) regulate power generation. Between the ITT and KGU lies the ecologically important Kafue Flats. The river gradient is gentle throughout the flats, and evaporation losses are significant. Therefore, releases from the ITT may not reach the KGU for up to two months, which attenuates flows considerably. Two new hydropower schemes are planned on the Kafue River: at Itezhi Tezhi at the outlet of the reservoir and the Kafue Gorge Lower Dam (KGL). There has been some preliminary investigation into raising the level of the ITT as well.

Kariba (subbasin 6)

The Kariba subbasin has a mean annual precipitation (MAP) of 700 mm per year—the lowest total in the Basin (figure 2.8.). Nevertheless, Kariba contributes an estimated 8,400 km^3 per year to overall flow. The subbasin is located roughly in the middle of the ZRB. The lag between peak rainfall in the upper areas of the river's catchment (in December

Figure 2.7. Hydrograph of Kafue, subbasin 7 (rainfall, ETP and flow)



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
▨ ETP	179	140	124	121	109	124	119	111	98	107	134	157	1,523
■ Rain	24	121	256	241	196	134	32	5	1	0	0	1	1,011

Regulated	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
- - Drought	160.1	160.3	160.4	160.5	160.4	160.0	159.7	159.6	159.6	159.7	159.8	160.0	160.0
— Average	259.6	231.4	205.0	204.9	235.9	429.0	507.2	482.5	573.3	378.8	295.9	279.2	340.2

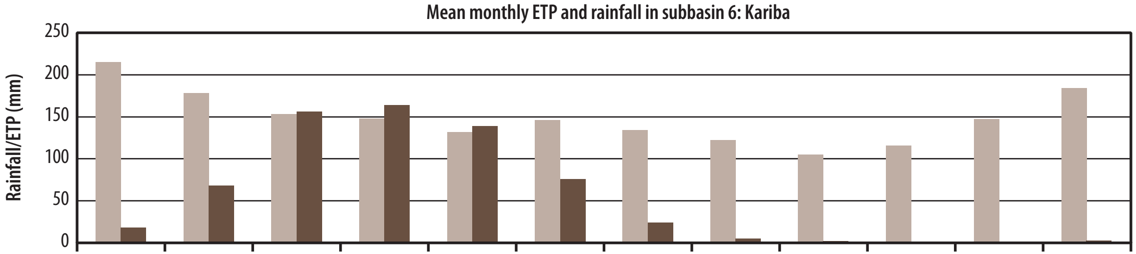
Unregulated													
-·- Drought	45.2	52.2	89.9	124.4	150.5	155.3	164.9	143.8	98.7	62.6	42.2	27.9	96.5
····· Average	150.2	107.4	163.5	275.1	420.9	606.3	709.0	625.8	486.8	396.6	304.2	219.2	372.1

and January) and the subsequent flood peak at the Victoria Falls (in April and May, estimated to be 21,690 km^3) is therefore considerable—around four months. Withdrawals for irrigation total 529 km^3 per year. Extraction occurs primarily in Zimbabwe through numerous dams. Potential for further irrigation is high, although mostly on the Zambian side. The Kariba Dam—located at the border of Zambia and Zimbabwe—creates Lake Kariba, the second-largest man-made lake in Africa after Lake Volta. The two hydropower plants, one on each side of the dam in each of the two countries, generate 30 percent of the hydropower capacity of the Zambezi River. Upstream, at Victoria Falls, three smaller hydropower plants have a total capacity of around 100 MW. The tremendous natural and ecosystem value of Victoria Falls makes further expansion unlikely. Katombara—some 60 kilometers north of the falls—has storage potential, but environmental constraints limit the feasibility of such a project. Batoka Gorge and Devils Gorge also have major hydropower potential, although only Batoka is economically feasible.

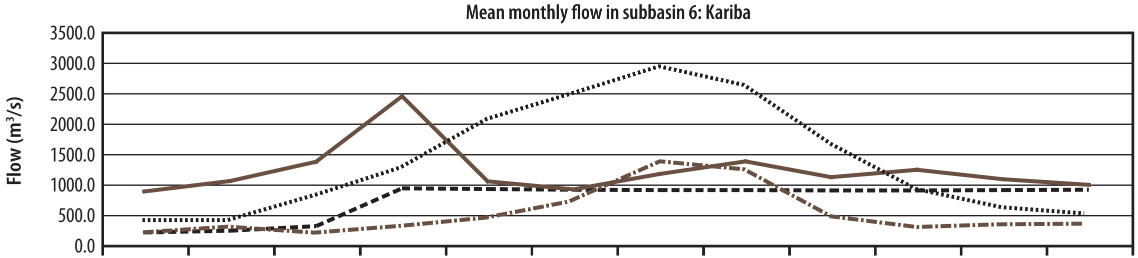
Luangwa (subbasin 5)

The Luangwa subbasin has a relatively high MAP of over 1,000 mm per year and a large surface drainage area (figure 2.9.). It therefore generates considerable runoff with total estimated annual volumes of 16,339 km^3, although that figure can fall to as low as 8,246 km^3 in drier years. Floods occur in February, March, and April. The largest monthly flow volume is estimated to be 8,432 km^3. Because the Luangwa subbasin is a headwater catchment, the lag between rainfall and floods is usually short, although the length of the Luangwa River can extend it. Much of the natural resources in the Luangwa catchment area—especially along the main stem of the river—are protected for conservation purposes. Extraction of

Figure 2.8. Hydrograph of Kariba, subbasin 6 (rainfall, ETP and flow)

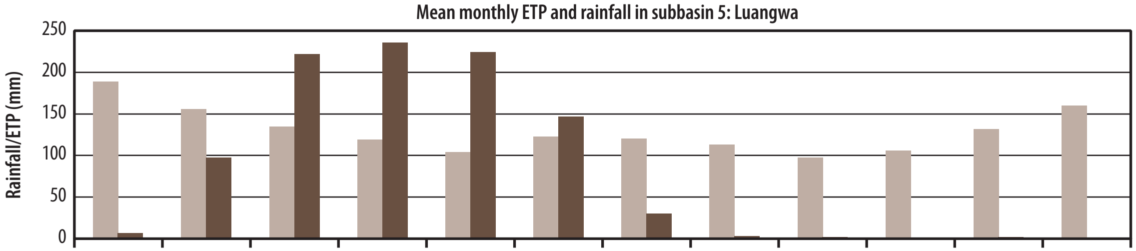

Mean monthly ETP and rainfall in subbasin 6: Kariba

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
▨ ETP	215	178	153	148	132	146	134	122	105	116	147	184	1,780
■ Rain	18	68	156	164	139	76	24	5	1	0	0	2	653

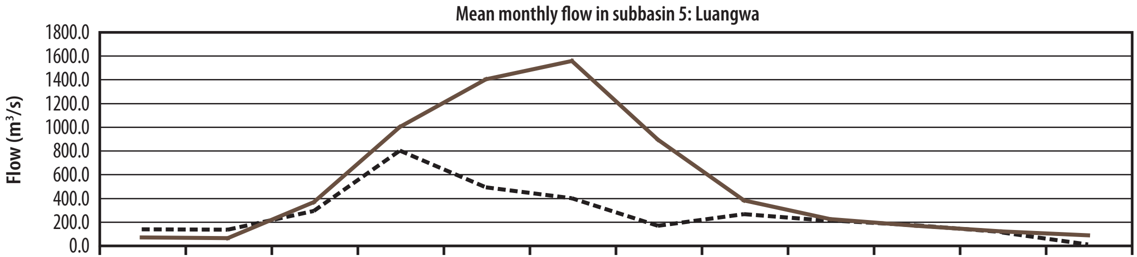

Mean monthly flow in subbasin 6: Kariba

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
Regulated													
- - Drought	199.7	231.8	302.9	927.2	913.2	901.4	897.6	893.8	891.8	893.2	897.5	902.1	737.7
— Average	875.9	1,047.9	1,364.4	2,436.8	1,042.2	905.8	1,162.7	1,368.8	1,111.2	1,228.6	1,075.5	981.9	1,216.8
Unregulated													
-·- Drought	200.0	292.6	215.2	327.1	464.0	725.2	1,369.8	1,224.3	473.5	296.4	344.6	335.1	522.3
····· Average	386.7	402.3	817.4	1,265.3	2,073.2	2,485.3	2,927.6	2,612.4	1,657.4	910.1	605.0	490.4	1,386.1

Figure 2.9. Hydrograph of Luangwa, subbasin 5 (rainfall, ETP and flow)


Mean monthly ETP and rainfall in subbasin 5: Luangwa

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
▨ ETP	189	156	135	119	104	123	120	113	98	106	132	160	1,555
■ Rain	6	98	222	236	224	147	30	3	1	0	1	0	968


Mean monthly flow in subbasin 5: Luangwa

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
- - Drought	126.5	125.4	282.2	792.3	482.9	389.9	157.8	257.1	200.7	157.8	100.3	0.0	256.1
— Average	60.1	52.1	358.1	990.5	1,391.6	1,546.9	882.2	371.4	214.8	157.7	111.4	76.7	517.8

water for irrigation is very low (120 km^3 per year), but potential is high. There are three small hydropower plants on the tributaries of the Luangwa River the Mulungushi, the Lunsemfwa, and the Lusiwasi. Power is generated from storage water, though detailed information is not readily available.

Mupata (subbasin 4)

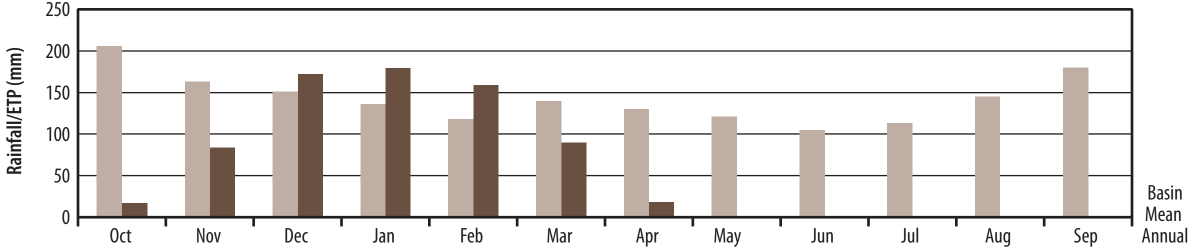
Because of a small catchment surface area, the Mupata subbasin has little incremental runoff (figure 2.10.). However, it accumulates the flow of the Kariba and Kafue subbasins, and therefore, its total runoff volume is relatively high, at 74,900 km^3 per year. During the hydrological years 1975–77, the regulating influence of Kariba Dam appears to have reduced the flow to almost zero. Lag time between rainfall and floods is consistent with those of Lake Kariba and the upstream subbasins of Kariba, Kafue, Barotse, and Kafue Flats. Large parts of the Mupata subbasin—such as Mana Pools, a UNESCO heritage site—are protected. Irrigation demand for water in the subcatchment is low (303 km^3 per year). Yet proximity to Lusaka makes irrigation potential high in some areas. There are no hydropower plants in the Mupata subbasin. The Mupata Gorge has potential for a 600 MW plant, although such a project is not feasible because it would inundate the protected Mana Pools.

Shire River and Lake Malawi/Niassa/Nyasa (subbasin 3)

The Shire River and Lake Malawi/Niassa/Nyasa subbasin has the second-highest runoff of the Zambezi subbasins (figure 2.11.). Estimated annual runoff volumes are as high as 18,150 km^3, which is almost 20 percent of the Basin's total. Unlike other subbasins, the Shire River and Lake Malawi/Niassa/Nyasa has high rainfall in two nonconsecutive months: January and March. As a result, the subbasin often has two flood peaks. In March, runoff is at its highest at an estimated volume of

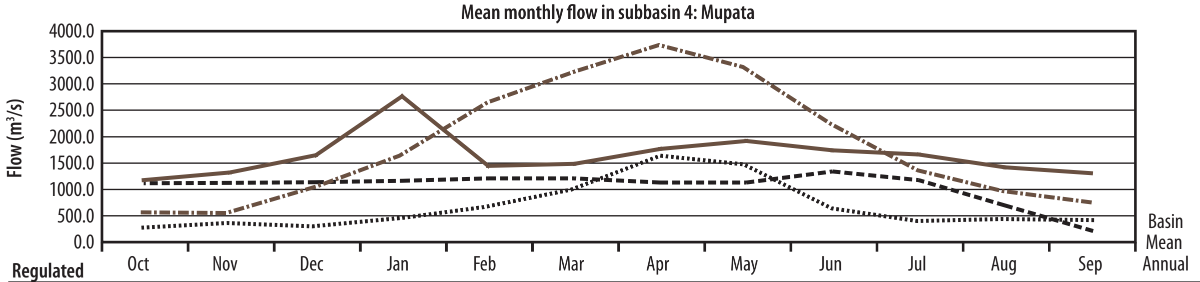
Figure 2.10. Hydrograph of Mupata, subbasin 4 (rainfall, ETP and flow)

Mean monthly ETP and rainfall in subbasin 4: Mupata



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
■ ETP	206	163	151	136	118	140	130	121	105	113	145	180	1,708
■ Rain	17	84	172	179	159	90	18	3	1	0	0	1	724

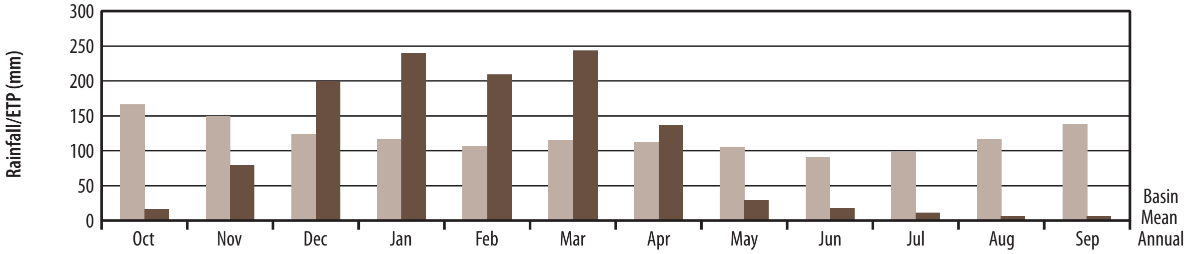
Mean monthly flow in subbasin 4: Mupata



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
Regulated													
- - Drought	1,093.3	1,095.6	1,109.2	1,136.9	1,179.5	1,179.2	1,102.9	1,101.3	1,314.8	1,147.0	668.1	194.7	1,026.9
— Average	1,149.3	1,296.6	1,619.7	2,741.1	1,419.0	1,455.0	1,738.3	1,888.8	1,714.3	1,632.6	1,392.1	1,277.7	1,610.4
Unregulated													
···· Drought	254.1	340.1	282.0	440.5	643.6	967.9	1,613.2	1,441.6	614.6	390.8	409.2	382.0	648.3
-·- Average	550.6	527.0	1,031.2	1,639.8	2,635.1	3,211.8	3,705.0	3,275.7	2,174.1	1,331.9	929.9	726.3	1,811.5

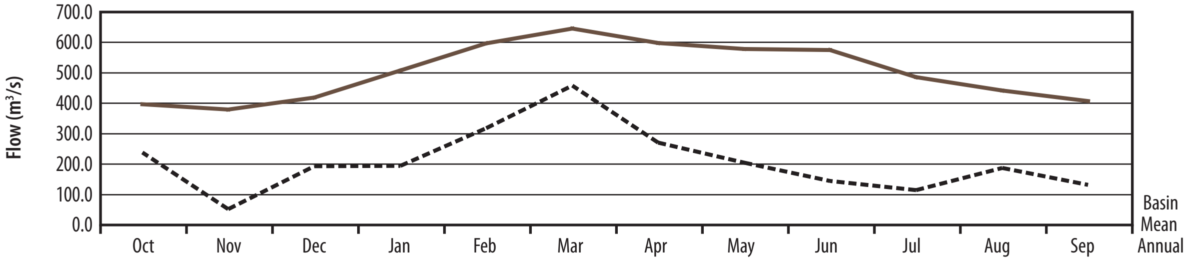
Figure 2.11. Hydrograph of Shire River and Lake Malawi/Niassa/Nyasa, subbasin 3 (rainfall, ETP and flow)

Mean monthly ETP and rainfall in subbasin 3: Shire River and Lake Malawi/Niassa/Nyasa



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
▨ ETP	166	150	124	116	106	115	112	105	90	98	116	138	1,436
■ Rain	16	79	200	240	209	243	136	29	18	11	5	5	1,191

Mean monthly flow in subbasin 3: Shire River and Lake Malawi/Niassa/Nyasa



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
-- Drought	233.2	48.0	188.8	189.6	313.4	453.7	266.4	200.6	139.5	110.3	182.6	127.1	204.4
— Average	392.7	375.3	414.8	503.7	592.7	641.6	593.6	573.7	570.2	481.1	437.2	402.5	498.3

6,637 km^3. A lesser peak occurs in June. The lowest annual volume is estimated to be 9,174 km^3, which is still considerable. The small difference between mean flow and drought flow suggests that the Shire River and Lake Malawi/Niassa/Nyasa subbasin is not as susceptible to drought as the rest of the ZRB. Although the Shire River and Lake Malawi/Niassa/Nyasa subbasin is a headwater catchment, it has a large attenuating effect on floods. The lag between rainfall and floods is therefore significant. Irrigation demand is high (over 647 km^3 per year), and potential for further irrigation is substantial. The Shire River has several small- to medium-sized hydropower plants, which contribute six percent of the ZRB's total power-generating capacity. Additional small- to medium-sized plants are also feasible.

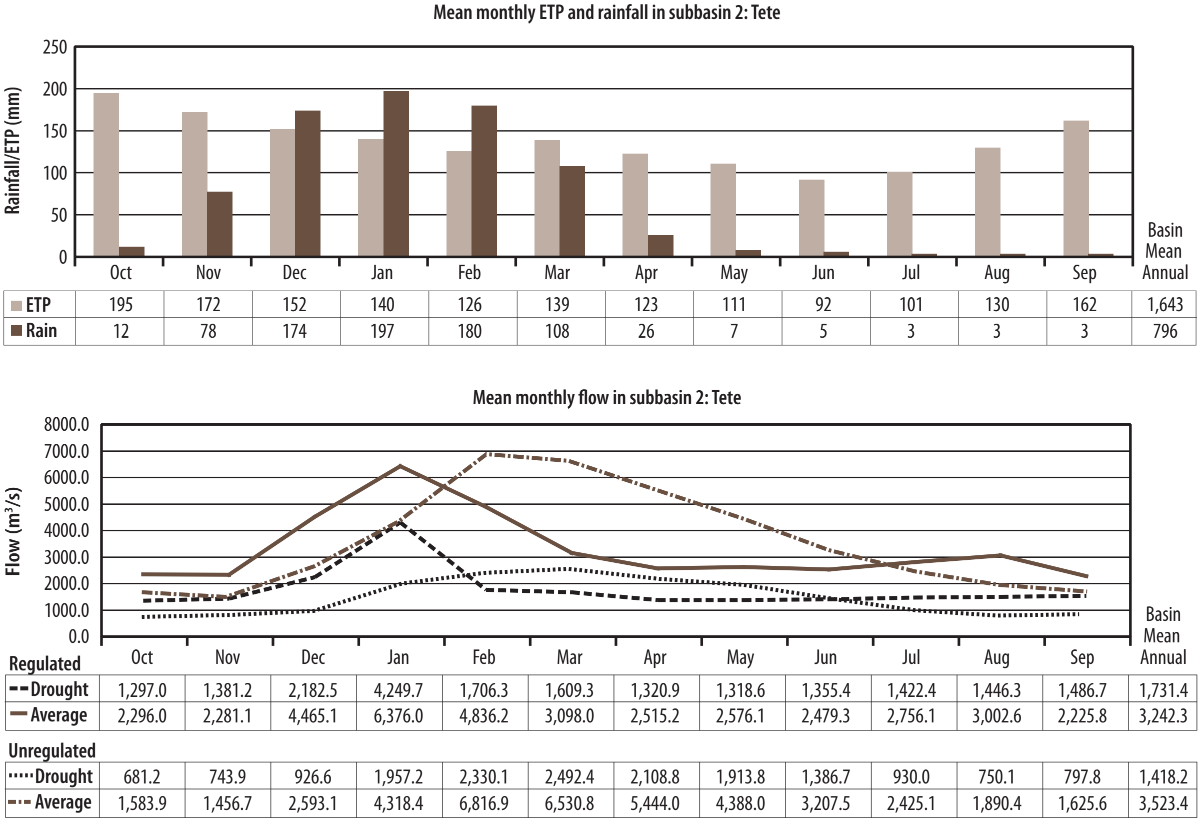
Tete (subbasin 2)

The Tete subbasin accumulates all the flow from the ZRB except that from the Shire River and Lake Malawi/Niassa/Nyasa subbasin (figure 2.12.). Cumulative runoff volume is estimated at 111,000 km^3 per year at the outlet of the Tete subbasin. Peak flow volume of 18,023 km^3 occurs in February. Lake Kariba and the Lake Cahora Bassa largely control floods at the outlet. These releases have not been sequenced to mirror natural flood patterns in the Basin in the months of March and April. Peak flood, although difficult to estimate accurately, is substantially reduced compared to the natural flood peak. Extraction of water for irrigation is high (655 km^3 per year) with Lake Kariba and Lake Cahora Bassa providing the majority of supply, and are hence not susceptible to droughts. A large dam and hydropower plant are planned at Mphanda Nkuwa in Mozambique. There are also areas downstream from Mphanda Nkuwa with large hydropower potential.

Zambezi Delta (subbasin 1)

The cumulative runoff in the Zambezi Delta subbasin is estimated to be 130,000 km^3 per year (figure 2.13.). Although a lack of flow gauges, along with

Figure 2.12. Hydrograph of Tete, subbasin 2 (rainfall, ETP and flow)



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
■ ETP	195	172	152	140	126	139	123	111	92	101	130	162	1,643
■ Rain	12	78	174	197	180	108	26	7	5	3	3	3	796

Regulated	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
- - Drought	1,297.0	1,381.2	2,182.5	4,249.7	1,706.3	1,609.3	1,320.9	1,318.6	1,355.4	1,422.4	1,446.3	1,486.7	1,731.4
— Average	2,296.0	2,281.1	4,465.1	6,376.0	4,836.2	3,098.0	2,515.2	2,576.1	2,479.3	2,756.1	3,002.6	2,225.8	3,242.3
Unregulated													
····· Drought	681.2	743.9	926.6	1,957.2	2,330.1	2,492.4	2,108.8	1,913.8	1,386.7	930.0	750.1	797.8	1,418.2
-·- Average	1,583.9	1,456.7	2,593.1	4,318.4	6,816.9	6,530.8	5,444.0	4,388.0	3,207.5	2,425.1	1,890.4	1,625.6	3,523.4

uncertainty regarding catchment boundaries, makes it difficult to determine the incremental contribution of the delta area. Rough estimates suggest an annual volume of 3,600 km^3. The long river reach upstream of the Delta and the attenuation effects of Lake Kariba, Lake Cahora Bassa, and, to a lesser extent, Lake Malawi/Niassa/Nyasa explain the long lag time between rainfall and floods in the Delta. Such floods are thus foremost due to local rainfall and inflow from the Shire River and Lake Malawi/Niassa/Nyasa subbasin. Since the construction of the Kariba and Cahora Bassa dams, major floods originating in the middle and upper reaches of the Basin have only once influenced the flow in the Delta region. The greatest recorded flood volume in recent times was measured at 14,700 m^3 per second. The highest flood would have reached around 19,000 km^3 per second if not for the impact of the Kariba and Cahora Bassa dams (Beilfuss and Brown 2006). Withdrawals of water for irrigation in the Delta are comparatively high (127 km^3 per year). Despite the high potential for irrigation in the Delta, there is a shortage of river flow to support development. The river gradient is too flat to support hydropower plants.

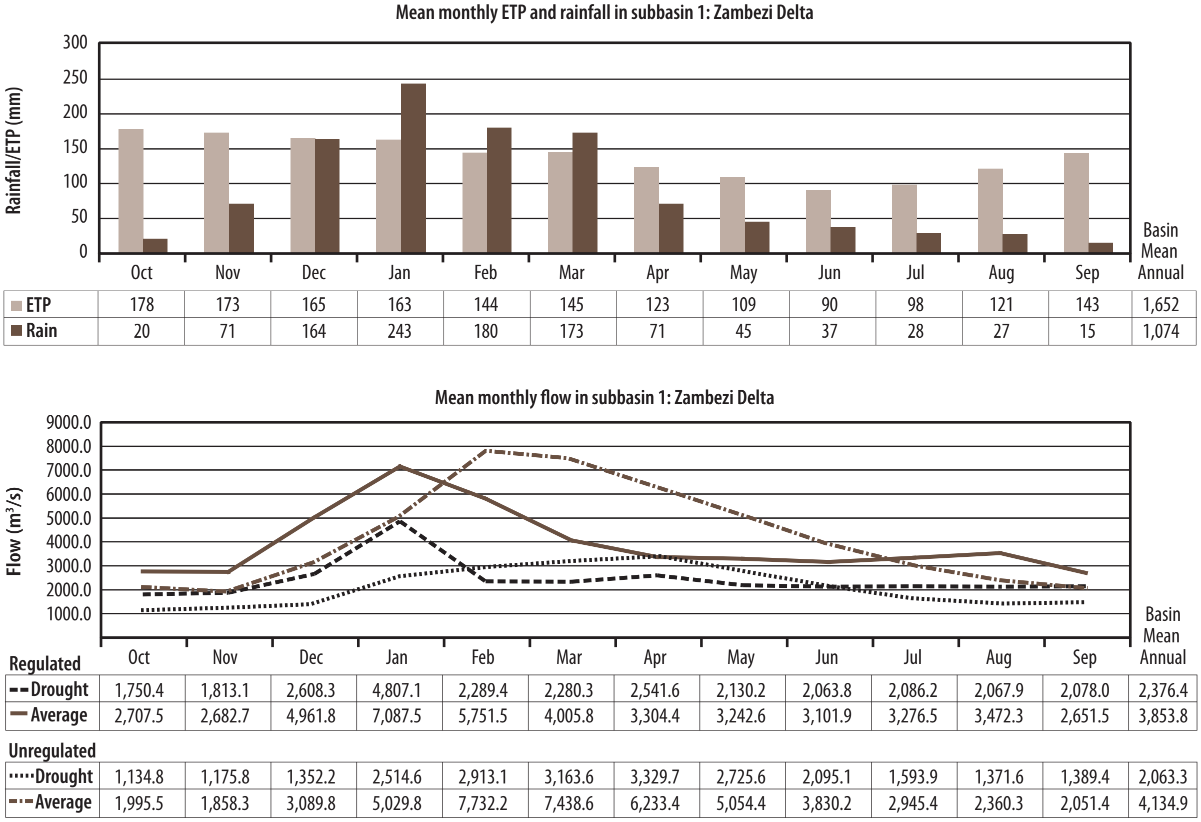
2.2 EXTREME EVENTS

2.2.1 Floods

Floods in the Kafue River Basin

The Kafue catchment has two major natural flood control features. As a result, outflows are low compared with rainfall. The Kafue River has an average flow rate of 350 m^3 per second near the confluence with the Zambezi River. The average total annual flow is only 6.2 percent of the catchment's average annual rainfall of 1,057 millimeters. The main fea-

Figure 2.13. Hydrograph of Zambezi Delta, subbasin 1 (rainfall, ETP and flow)



Mean monthly ETP and rainfall in subbasin 1: Zambezi Delta

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
■ ETP	178	173	165	163	144	145	123	109	90	98	121	143	1,652
■ Rain	20	71	164	243	180	173	71	45	37	28	27	15	1,074

Mean monthly flow in subbasin 1: Zambezi Delta

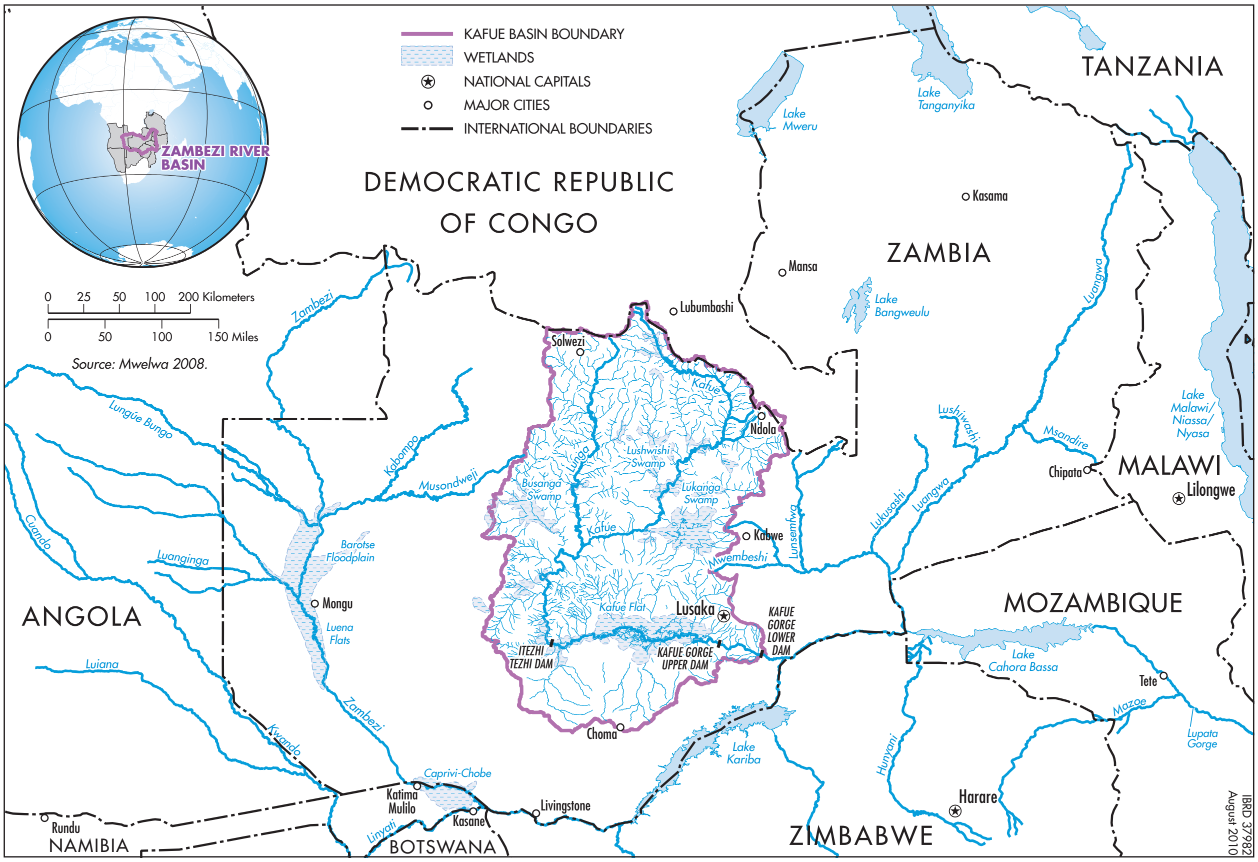
Regulated	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Basin Mean Annual
-- Drought	1,750.4	1,813.1	2,608.3	4,807.1	2,289.4	2,280.3	2,541.6	2,130.2	2,063.8	2,086.2	2,067.9	2,078.0	2,376.4
— Average	2,707.5	2,682.7	4,961.8	7,087.5	5,751.5	4,005.8	3,304.4	3,242.6	3,101.9	3,276.5	3,472.3	2,651.5	3,853.8
Unregulated													
····Drought	1,134.8	1,175.8	1,352.2	2,514.6	2,913.1	3,163.6	3,329.7	2,725.6	2,095.1	1,593.9	1,371.6	1,389.4	2,063.3
-·- Average	1,995.5	1,858.3	3,089.8	5,029.8	7,732.2	7,438.6	6,233.4	5,054.4	3,830.2	2,945.4	2,360.3	2,051.4	4,134.9

tures of the Basin are extensive dambos, the Lukanga Swamps, and the Kafue Flats, which are known to be prone to flooding. During times of peak flow, the Kafue River also experiences riverine flooding that is quite extensive in some areas. Such flooding can make routes to the river impassable, which disrupts ferry operations and other activities along the river banks. Figure 2.14. illustrates some flood-prone areas in the Kafue River Basin (Mwelwa 2008).

A strategy for flood management in the Kafue Basin was prepared in 2006 and translated into short-, medium-, and long-term action plans (see WMO/GRZ/APFM 2006 for more details). In 2007 and 2008, Zambia experienced widespread floods. The floods of 2008 were more severe, more widespread, and caused greater damage than those of 2007 (Mwelwa 2008). In 2007, rainfall came early in the season to most parts of Zambia (early November), especially in the southern half of the country. The northern half experienced delayed onset (last 10 days of December 2008). Heavy rainfall in the southern half of the country also caused localized flash floods in the Zambezi and Luangwa valley areas (Mwelwa 2008).

Rainfall during the period November 2007 to January 2008 exceeded that of the 2006/2007 season. Most of the southern half of the country (western, eastern, and southern provinces) experienced severe flash floods in low-lying areas (Luangwa and Zambezi Rift Valleys). Water logging in the central, southern, and western plateaus damaged bridges, culverts, habitations, school buildings, health centers, and other infrastructure. Infrastructure damage also hindered access to basic services such as healthcare providers, schools, and markets (Mwelwa 2008). For example, classroom blocks in 44 schools—40 basic schools and four community schools—suffered damage or collapsed due to heavy rainfall and flooding. Sanitation facilities also collapsed or flooded, rendering the schools unfit for

Figure 2.14. Flooding in Kafue River Basin



Source: Mwelwa 2008.

learning. Most feeder roads from district centers to the affected areas were flooded and only partially accessible. Bridges and culverts either collapsed or were submerged. This reduced the supply of goods and services to these areas and left the communities cut off from other districts. Rehabilitation and repair of damaged infrastructure has strained the national budget (Mwelwa 2008). By February 2008, almost half of Zambia's 72 districts were affected by the floods which directly lead to very poor agricultural yields with damaged food (maize, millet, sorghum, and cassava) and cash crops (rice, sweet potatoes, and cotton). Major cash generating crops—such as maize, cotton, tobacco, and groundnuts—were waterlogged, causing nutrient leaching. A total of 274,800 affected people (45,800 households), comprising of 7,422 displaced and 267,378 nondisplaced people, were in dire need of humanitarian relief.

Floods in the Lower Shire River Basin

Floods occur in the south, particularly in the Lower Shire River floodplain and the lakeshore areas of Lake Malawi/Niassa/Nyasa, Lake Malombe, and Lake Chilwa. Low-lying areas such as Lower Shire Valley and some localities in Salima and Karonga are more vulnerable to floods than higher elevated areas. Flooding problems in the lower stretches of the Shire River and the Ruo River floodplains are generally caused by brief high-flow periods of the Ruo River. Floods also occur in the lower reaches of the Songwe River in the northern region (www.dartmouth.edu). Since 2000, floods in Malawi have affected considerable number of people (180,000 in 2007; 80,000 in 2003; 250,000 in 2000; and 500,000 in 2001). Lower Shire flooding generally combines with flooding of the Lower Zambezi floodplain downstream of Lupata Gorge.

Floods in the Lower Zambezi River flood plains (downstream of Cahora Bassa Dam)

Flooding of the Lower Zambezi floodplain downstream of Lupata Gorge—located some 80 kilometers downstream of the city of Tete in Mozambique—is a natural phenomenon that has been mitigated since 1962 by the operation of Lake Kariba, and more recently since 1975 by the operation of Lake Cahora Bassa.

Beilfuss and Santos (2001) remarked "after the completion of Kariba Dam in 1959, large flooding events in the Zambezi Delta region were greatly curtailed". The 1969 flood was not remarkable in terms of the peak water levels in the Delta (about 7.39 meters), but water levels remained above flood stage for 222 days from early January through mid-August. Local villagers refer to this strange dry-season flood as the *Cheia Nabwariri* ("water coming from the ground"). The unusual pattern of flooding is the result of prolonged releases from Kariba Reservoir. Kariba received a near-record inflow volume of 79 km^3—comparable to inflows to Kariba Gorge during the 1958 flood season—including the third-highest recorded flood discharge from the headwaters region (8,204 m^3 per second). Unlike the 1958 floods, however, most of this inflow volume was stored by the reservoir, and floodwaters were subsequently discharged through the Kariba's sluice gates during the dry season to draw down reservoir levels according to the design flood rule curve. Kariba thus significantly reduced peak flooding in the Zambezi Delta, but at the same time greatly prolonged the total duration of flooding. In several other years during which runoff from the Zambezi headwaters regions was among the highest on record—including 1961 (6,032 m^3 per second), 1962 (5,425 m^3 per second), 1966 (5,233 m^3 per second), 1968 (5,340 m^3 per second), and 1970 (4,783 m^3 per second)—there were relatively insignificant floods at Marromeu due to the Kariba regulation.

Construction of the Cahora Bassa project began in 1969. Filling of the reservoir began in 1974 and was completed in 1976. Shortly thereafter civil war broke out in Mozambique, and Cahora Bassa and Songo became a militarized enclave with little communication with downstream areas. When the power line linking Cahora Bassa to South Africa was sabotaged in the early 1980s, the reservoir operated at a reduced level. No significant outflows were released for the subsequent 20 years, except in 1978 between February to July and during a few floods during the 1980s and 1990s. As a result of low releases at Cahora Bassa after the loss of the main power lines linking Songo to the Apollo station in South Africa, people started settling in the floodplain areas, primarily to practice recession irrigation.

In 1978, flooding on the Lower Zambezi caused an estimated $62 million worth of damage. Flood relief operations cost about $40 million (Beilfuss and Santos 2001). HidroEléctrica de Cahora Bassa (HCB) operating data indicate that between February and July 1978, the Cahora Bassa reservoir received an inflow of 22.28 km^3 and released 20.63 km^3. Unfortunately, no record is available at the Lupata gauging station to assess the contribution to flooding of tributaries downstream of Cahora Bassa. The flood resulted from a combination of emergency releases from the Cahora Bassa Dam and heavy runoff from Lower Zambezi tributaries.

During 1978, prolonged rainfall in the Kariba catchment produced some of the highest inflows to the Kariba Reservoir on record. The Zambezi River Authority (ZRA) opened four of the six sluice gates at Kariba to prevent the overtopping of the dam. Maximum discharge reached 7,300 m^3 per second. Downstream, heavy runoff from the Luangwa catchment more than doubled the Zambezi River's flows below the Kariba, and the Cahora Bassa inflows steadily increased to a monthly total of 13,894 m^3 per second. During this period, the Cahora Bassa operated with only three or four sluice gates open. In late March, however, water levels neared design capacity, and reservoir managers opened the remaining sluice gates in rapid succession. On March 30, reservoir levels reached 327.9 meters, and Cahora Bassa released a peak discharge of 14,900 m^3 per second with all eight sluice gates and the emergency spill gate open. Peak discharge downstream at Muturara surged to 19,500 m^3 per second, and water levels at Marromeu spiked to 7.92 meters (Beilfuss and Santos 2001).

Many floodplain residents were unable to evacuate to higher elevations in time, 45 people died and more than 10,000 people were displaced. If the reservoir had released water in January and February, gradually stepping up the outflow to 7,000 m^3 per second, releases would have been significantly less than the maximum of 10,163 m^3 per second during the early part of April. This would have allowed adequate time to evacuate the most flood-prone areas (Beilfuss and Santos 2001). At the time, however, no medium-term inflow forecasting method was in place at Cahora Bassa, and communications between upstream and downstream operators were practically nonexistent.

In 1989, runoff from the Upper Zambezi was not sufficient to force the Kariba to spill floodwaters, but heavy runoff from the Luangwa Valley generated a peak inflow of 14,436 m^3 per second to the Cahora Bassa Reservoir. The Cahora Bassa operated to attenuate inflows and reduced the magnitude of downstream flooding. During peak flooding, however, reservoir levels approached design capacity, and outflows were rapidly stepped up from one sluice gate on February 6 to five sluice gates on February 12, reaching a maximum discharge of 7,938 m^3 per second. Combined with heavy runoff from the plateau region, runoff in the Zambezi Delta region surged to 11,000 m^3 per second. Although this peak discharge was less than the mean annual peak discharge prior to Kariba regulation (about 11,500 m^3 per second), the flood caused widespread damage to settlements that had encroached into the Delta floodplains. The flood is known locally as *Cheia Cassussa*, remembered locally because flood levels rose so rapidly there was no time to escape (Beilfuss and Santos 2001).

In 1997, flooding in the Zambezi Delta reached its highest level since 1978, with a peak of 7.61 meters at Marromeu. Flooding was generated almost entirely within the Lower Zambezi catchment. Maximum runoff from the Zambezi headwaters region was only 1,758 m^3 per second, one of the lowest peaks in the 75-year historic record, and the Kariba did not spill. Inflows to the Cahora Bassa from the Luangwa Valley rose sharply from less than 4,000 m^3 per second to a peak of 12,170 m^3 per second between February 9 and 15, but then fell again below 4,000 by February 25. The Cahora Bassa captured most of this brief surge, and maximum discharge from the dam was only 2,000 m^3 per second. Downstream of the Cahora Bassa, however, the lower Basin experienced the second-wettest year on record, with rivers in central Mozambique reaching flood stage in mid-January. The Pungue River to the south reached its highest water levels in 30 years, and the road linking Beira to Zimbabwe was severed. Runoff from the Shire Valley was the highest since the 1950s. Overall the flood peak was not remarkable—only the sixteenth-highest on record—but flooding known as the *Cheia N'selusso* ("flood of ill-fortune") ripped through new settlements on the Zambezi River banks. The media portrayed the flood as catastrophic and international evacuation efforts were widely televised (Beilfuss and Santos 2001).

The most prolonged floods in the Zambezi Delta since the construction of the Cahora Bassa Dam occurred in 2001. Very heavy rainfall in the headwaters region resulted in substantial inflows into Lake Kariba, and the Kariba Dam spilled floodwaters for the first time since 1981. Rainfall in the middle Zambezi catchment was also heavy, and inflows to the Cahora Bassa peaked at 13,978 m^3 per second on February 22 and again at 11,379 m^3 per second on March 15. As water levels in the Cahora Bassa reservoir approached design capacity, Mozambican authorities plead privately and publicly with the ZRA to close the sluice gates and reduce the Kariba outflows. Discharges from the Cahora Bassa were stepped up to 9,000 m^3 per second on March 7–8 through five sluice gates. Downstream the Luia and Revubue Rivers discharged a steady 2,000–3,500 m^3 per second, the Luenha contributed 1,000–1,500 m^3 per second, and heavy rains in the Shire Valley (that left five people dead and 22,454 people homeless) generated runoff from the Shire Basin comparable to the 1997 floods. Water levels at the Marromeu climbed above flood stage on January 20, and reached a maximum of 7.69 meters on March 9. The navy began evacuating people from the Delta region in January using rubber boats and helicopters. An estimated total of 81 people died and more than 155,000 people were displaced by the floods (Hanlon 2001). The damage could have been considerably worse if Hurricane Elise, which struck central Mozambique a year earlier, had hit the Delta region during peak flooding and forced Cahora Bassa authorities to open more sluice gates (Beilfuss and Santos 2001).

In January and February of 2007, the Mozambican government appealed for disaster relief and food for tens of thousands of people driven from their homes by the worst flooding in years. At least 30 people were killed in Mozambique after torrential rains across southern Africa caused the Zambezi River to burst its banks. Although the government learned the lessons of the 2001 floods, and swiftly launched missions by boat and helicopter to evacuate about 90,000 people from affected areas, it rapidly ran short of food for those collected in 33 temporary camps, and lacked tents and other essentials for many of them. Up to 285,000 people living along the Zambezi River valley were affected by the flood waters (www.guardian.co.uk/world/2007/feb/19/naturaldisasters.chrismcgreal).

In 2008, the stretch of the Zambezi River from Tete city to the river's mouth (500 kilometers to the east) was well above flood-alert level. All the Zambezi River's main tributaries—the Shire, the Revubue, and the Luenha—were also at very high levels and there were widespread impact on food production. A short overview of the hazardous impact of major floods between 1963 and 2008 is presented in table 2.3.

2.2.2 Droughts

Droughts are a natural phenomenon resulting from variability in rainfall. The accepted practice for dealing with droughts is to plan and design water supply schemes around the flow available during the worst recorded drought—not on the average flow available in the river. It is therefore important to ensure that flow records capture the worst drought on record.

Figure 2.15. shows a cumulative differential plot of the flow at Victoria Falls over the entire period of its records (1907 to 2006). The plot illustrates the extent to which flow deviates from the long-term mean over time. There was a period of prolonged drought from October 1907 to October 1920; and another prolonged drought began around 1980 and had not yet broken by 2006. From this analysis it can be concluded that the water resources simulation must include at least an early drought sequence or the most recent drought sequence. Since most of the gauging stations in the Zambezi River Basin were only constructed in the 1960s, there are insufficient data on the early drought period. The later drought period was therefore used.

Figure 2.16. shows the cumulative differential plot of the simulation period selected (October 1962 to September 2002). A cumulative differential plot of Lake Malawi/Niassa/Nyasa is also shown to demonstrate that the pattern of drought is not consistent throughout the Basin (figure 2.17.).

Table 2.3. Summary of major hazardous floods (1963–2008)

Year	Month of peak flood	Number of deaths	Number of affected people	Estimated damages (US$ million)	Maximum monthly flow in Tete (m^3/s)
1963	December to February	–	–	–	12,611
1969	February	–	–	–	10,993
1970	December	–	–	–	9,988
1971	January	–	–	–	11,717
1978	January and March	45	100,000	62	13,990
1989	February	–	–	–	10,583
2001	February	15	260,000	43	9,917
2007	January and February	29	285,000	71	–
2008	January	6	200,000	100	–

Figure 2.15. Zambezi River flow at Victoria Falls (1907–2006)

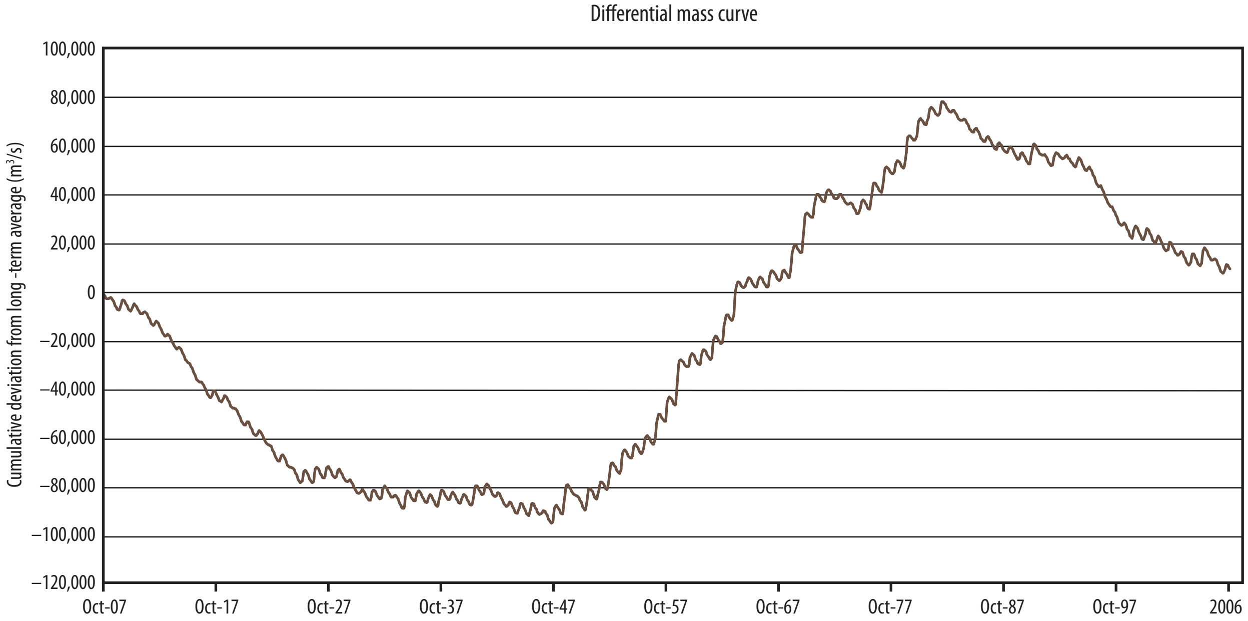
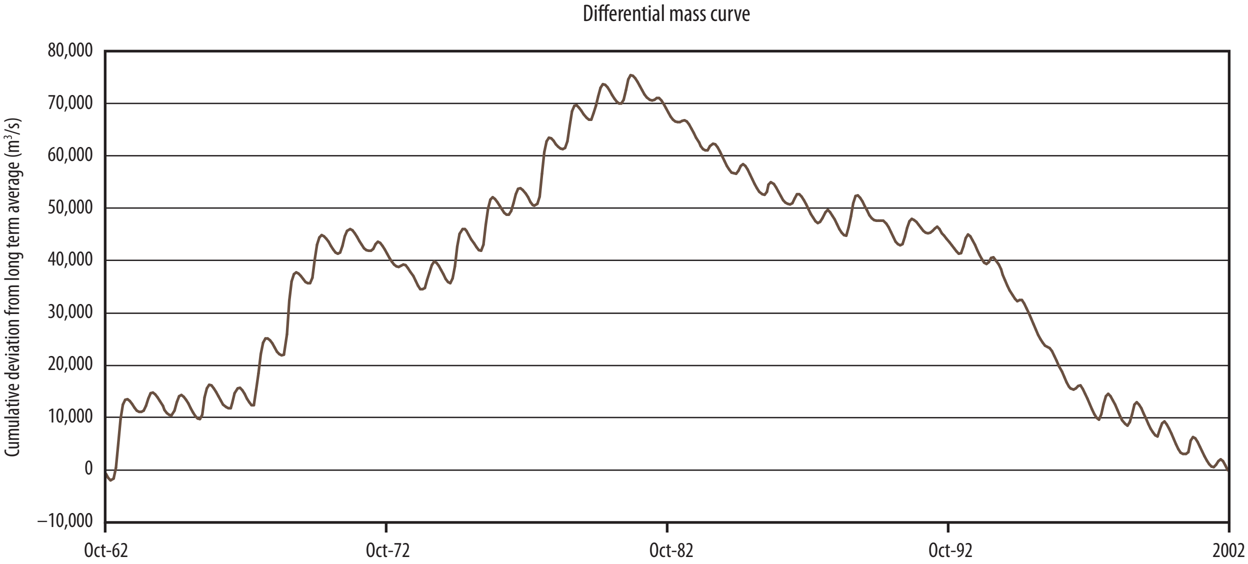


Figure 2.16. Zambezi River flow at Victoria Falls (1962–2002)

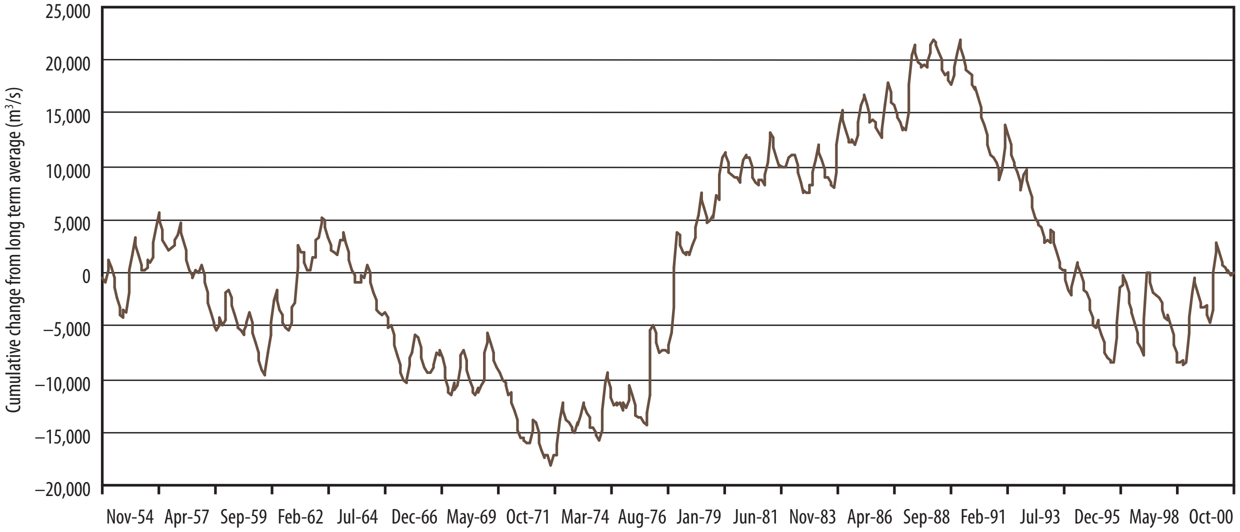


2.3 CLIMATE CHANGE

Climate variability has always affected the Zambezi River Basin. In Mozambique, for example, a drought year is best described as a year without major floods.

The Zambezi River has a low runoff efficiency (that is, volume of runoff per unit of area) and the Basin has a high dryness index (dryness of the vegetation based on remote sensing), indicating a high sensitivity to climate variability. Global warming

Figure 2.17. Flow into Lake Malawi/Niassa/Nyasa (1954–2000)



is expected to increase this variability and to raise temperatures (Euroconsult Mott MacDonald 2008a).

The ZRB receives a mean annual rainfall of about 950 millimeters. Most of this is concentrated in a single season. There is considerable variability across the Basin; some parts of the Basin are arid or semiarid while others receive large amounts of rainfall. The high spatial variability is exacerbated by the fact that areas of high water demand do not have high rainfall. Climate change is expected to materialize through changes in extreme events such as droughts and floods, affecting agricultural crop and livestock production as well as wildlife population. Furthermore, rising temperatures are expected to affect fish production from the major lakes and reservoirs, to cause higher evaporation from those main water bodies, and to reduce the productivity of main agricultural crops. The ecosystems of the wetlands will be affected by changing runoff patterns.

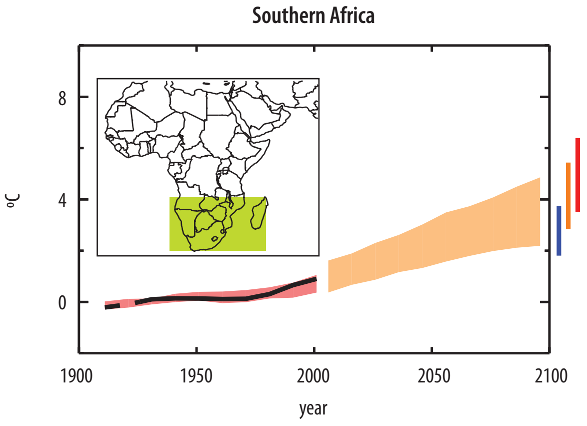
Precise assessments of climate change in Africa are not yet complete and are often limited to mean temperature and precipitation. Relatively little is known about changes in extremes. For southern Africa, the Intergovernmental Panel on Climate Change (IPCC) distinguishes four zones with a more or less uniform rainfall pattern. Area-averaged rainfall series for northeast South Africa, Zimbabwe, western Mozambique, southern Malawi, and Zambia show that multi-decade rainfall oscillations have occurred during the 20th century. The models generally show a drying trend for much of the 21st century, although decade-to-decade rainfall fluctuations should continue.

The simulated annual climatic cycles in a warmer climate show that the rainfall season may begin one month later than the recorded norm, effectively shortening the duration of the rainy seasons. This delayed seasonal rainfall onset is predicted in the northern parts of southern Africa as well.

Extremely low rainfall is predicted to become more common over central South Africa and Lesotho, increasing about 50 percent by around 2100. Most models simulate an increase in extreme dry events over the Kalahari of up to 30 percent. This is likely to prompt an eastward expansion of the desert. According to the IPCC models, the frequency of extremely dry austral winters and springs will increase to roughly 20 percent, while the frequency of extremely wet austral summers will double in southern Africa.

Adapting to climate change requires strategies to meet four objectives: to strengthen flood management and support it at the regional level; to improve regional and national drought-coping

Figure 2.18. Temperature anomalies in southern Africa



Source: IPCC 2007.

mechanisms; to reassess the adequacy of river regulation and consider the enhancement of infrastructure; and to make use of the changed regional and global development opportunities presented by climate change—in particular by using the Basin as a carbon sink.

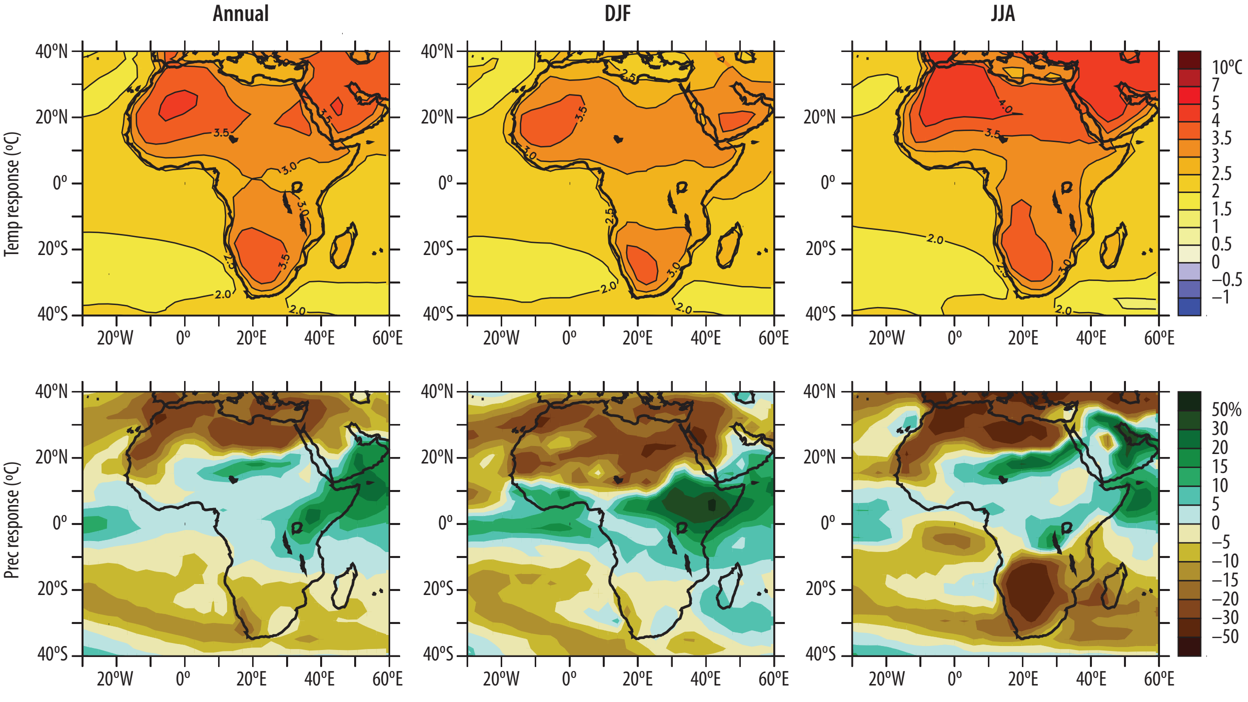
Figure 2.18. presents temperature anomalies in relation to 1906 to 2005 for southern Africa (black line) as simulated by IPCC climate models (area shaded red) and as projected for 2001 to 2100 (area shaded orange). The bars at the end of the area shaded orange represent the range of projected scenarios for 2091 to 2100 in relation to estimated carbon dioxide (CO_2) emission (low in blue, medium in orange, and high in red).

Figure 2.19. presents the annual mean temperature change between 1980 to 1999 and 2080 to 2099 for December to February, and June to August. The bottom row reflects fractional change in precipitation. Table 2.4. presents the percentage reduction in Basin yield for the five major subareas of the ZRB as well as the percentage irrigation deficit for year 2030 as a result of a 1.5 centigrade increase in ambient temperature.

The assumptions related to the above changes in Basin yield and irrigation deficit are:

- Percent change relates to historic (CRU 1961–90).
- Method is weighted by an average based on the U.S. Geological Survey (USGS) Class 4 catchment area.

Figure 2.19. Temperature and precipitation changes over Africa



Source: IPCC 2007.

Table 2.4. Impact of climate change on the Zambezi River Basin in year 2030

	% change in 2030	
Region/subbasin	**Basin yield**	**Irrigation deficit**
Delta	–13	27
Middle Zambezi	–24	17
Upper Zambezi	–16	13
Kafue	–34	21
Shire River and Lake Malawi/Niassa/Nyasa	–14	15

Source: World Bank 2009.

- Emission scenario A1B.
- Global Circulation Model: midrange of 23 models.

2.4 OVERVIEW OF THE BASIN BIOPHYSICS

2.4.1 Biomes and river zones

Biomes are communities classified by their vegetation and organisms. Along the Zambezi River Basin, there are four main biomes and three phytochoria, i.e. broad areas of plant assemblages (White 1983 in Timberlake 2000).

Virtually the entire Basin—95 percent—is in the Zambezian biome. This is a subtropical area of moist or dry woodland and grassland that experiences a marked dry season. The Zambezian biome is sometimes divided into areas of greater moisture, characterized by miombo broad-leaved woodland cover, and areas that are drier, with mopane, or *Acacia* woodland cover. This corresponds to part of the Zambezian phytochorion, which is a center of endemism (White 1983). The northwest part of the Basin, 1.5 percent of its total area, lies in the Congolian biome. This is a tropical area of high forest cover that experiences high rainfall and does not have a clearly defined dry season. This biome roughly corresponds to the area of the shared boundary between the Zambezi River and the Congo River systems. The eastern part of the Basin is composed of a scatter of areas at higher altitude (1,800–2,000 meters above sea level) falling within the Montane biome. These make up 2.5 percent of the Basin's total area. The Montane biome is characterized by a temperate climate and moist forest, heath, and grassland cover. The fauna and flora are similar to those of the Eastern Escarpment Mountains, which stretch from Ethiopia through Kenya, Uganda, and Tanzania to the Drakensberg and the southwestern cape in South Africa. The Montaine biome corresponds to the Afromontane phytochorion, which is a center of endemism (White 1983). Its vegetation is markedly different from surrounding areas and has a rich diversity of species, rainforest, montane grasslands, and fynbos-like shrubland. The southeastern corner of the Basin, corresponding to one percent of its total area, is located in the Coastal biome. This is a tropical area with dry forest, woodland, and grassland. Species within the Coastal biome are typical of those on the East African coastline. The biome corresponds to parts of the Zanzibar-Inhambane phytochorion, which is a regional transitional zone (White 1983).

Seventy-five percent of the Basin's area lies within the part of the Zambezian Biome that receives considerable rainfall. The swamps and pans, making up four percent of the Basin, are highly productive and economically vital (Timberlake 2000). They provide a wealth of natural resources such as fish, materials for construction and crafts, and grazing for livestock. Because of the year-round presence of water and ecosystem services, many people depend on them for livelihood and settlement. Important wetland plants for construction and craft include papyrus (*Cyperus papyrus*), rushes (*Typha*), and reeds (*Phragmites*). Many plants, such as the water lily (*Nymphaea*), are used for food. Certain wetland plants that have been introduced to the wetlands have become pests. Plants such as the water hyacinth (*Eichhornia crassipes*), water lettuce (*Pistia stratiotes*), Kariba weed (*Salvinia molesta*), and water fern (*Azolla*), are causing problems including hypoxia that leads to fish mortality, blockage of channels by excess vegetation, and spread of disease-causing aquatic invertebrates.

The Zambezi River biophysical system is commonly organized into three sections:

- The Upper Zambezi (from the headwaters to Victoria Falls) is characterized by a vast inland drainage basin with little topographical relief. Rivers have merged with others through slight geological movements and this, along with a relatively flat terrain and few natural physical barriers, has allowed aquatic organisms to migrate along rivers and across floodplains through a large part of the subcontinent.

- The Middle Zambezi (from Victoria Falls to the Lupata Gorge, downstream of Tete in Mozambique) is a younger, more heterogeneous landscape that includes the Luangwa Valley, most of northern Zimbabwe, and Lake Malawi/Niassa/Nyasa. The river's biological characters have been substantially modified by the Kariba and Cahora Bassa dams.
- The Lower Zambezi (from Lupata Gorge to the coast) includes the lower Shire River downstream of Kapichira Falls. This part of the Zambezi River is characterized by floodplains, anastomosing and braided channels, and shifting sandbanks with extensive grasslands, swamps, dunes, and mangroves along the coast.

The estimated numbers of recorded animal and plant species found in the ZRB indicate the presence of 200 mammal species, 700 bird species (of which 15–20 are endemic to the Basin and 167 linked to wetlands), 165 fish species with more than 500 species endemic to Lake Malawi/Niassa/Nyasa, 200 reptile species, and about 90 amphibian species (Chenje 2000). Apart from 210 dragonfly species, 1,100 butterfly species, and 98 mollusk species, the invertebrate fauna is understudied. The number of species is likely to be in the hundreds of thousands. The Basin's main hotspot for biodiversity is Lake Malawi/Niassa/Nyasa, with its extraordinary proliferation of fish species and other faunal groups. For example, 47 of the 98 mollusk species in the Basin appear in Lake Malawi/Niassa/Nyasa, of which 23 species are endemic. Scattered throughout the Basin are areas with rare or endemic species and areas with very high numbers of animals.

2.4.2 Bioregions and ecoregions

In 1998, an international group of freshwater specialists delineated a preliminary set of bioregions and freshwater ecoregions for Africa. An ecoregion is defined as "a large area of land or water containing a distinct assemblage of natural (plant and animal) communities and species . . . whose boundary approximates its original extent before major land-use changes" (Thieme and others 2005). Bioregions are combinations of ecoregions with similar biogeographic histories. Eleven bioregions and 93 freshwater ecoregions were delineated, with the ecoregion boundaries usually following drainage basin boundaries. Eight ecoregions encompass the ZRB (each is summarized, along with its conservation priority class, in tables 2.5. and 2.6.).

The Upper Zambezi – ecoregion 76, Zambezian Headwaters

This ecoregion of savanna-dry forest rivers covers the headwater reaches of the Okavango, Zambezi, and Kafue Rivers. Lying mostly in Angola, with some parts in Zambia, it is bioregionally outstanding with a conservation status of "relatively intact" and a conservation priority class of V. It encompasses the headwaters of the major upper tributaries: the Lungúe Bungo, Luanginga, Cuando/Chobe, Luena, Dongwe, and Kabompo Rivers; the Kafue River and its major tributary; and, the Lunga River.

In the early tertiary period, the drainage of the Upper Zambezi region through the Cunene, Okavango, Upper Zambezi, and Kafue Rivers was toward the southwest, emptying into the sea in the proximity of the present-day Orange River mouth. This, in addition to the capture of rivers along the Zambezi-Congo divide, resulted in a very similar set of fish to be found in the headwaters of these rivers. In the Plio-Pleistocene period, the Upper Zambezi and the Kafue were captured by the Middle Zambezi, but this had minimal effect on the fish species of the headwaters because the Kafue Gorge and Victoria Falls presented impassable barriers for upstream migration (Skelton 1994).

These upland tropical rivers are perennial and characteristically steep in places, but also include extensive networks of grassy dambos—seasonally waterlogged areas—along drainage lines. There is dense gallery forest along the major watercourses and some dense patches of evergreen forest, with very rare species of great conservation importance such as *Marquesia*, *Berlinia giorgii*, and *Lannea*

Table 2.5. Zambezi River Basin Ecoregions

Bioregion	Main freshwater ecoregions in the Zambezi River Basin	Freshwater ecoregion number
Floodplains, swamps, and lakes	Kafue	8
	Upper Zambezi floodplains	16
Highland and mountain systems	Mulanje	43
Large lakes	Lake Malawi/Niassa/Nyasa	53
Savanna—dry forest rivers	Zambezian headwaters	76
	Zambezian (Plateau) Highveld	78
	Middle Zambezi Luangwa	69
	Lower Zambezi	66

Source: Thieme and others 2005.

Table 2.6. Priority classification system for conservation action, based on biological distinctiveness and conservation status

Priority class for conservation	Description
I	Globally outstanding ecoregions that are highly threatened.
II	Continentally outstanding ecoregions that are highly threatened.
III	Globally or continentally outstanding ecoregions with relatively intact aquatic systems.
IV	Bioregionally outstanding and nationally important ecoregions that are highly threatened.
V	Bioregionally outstanding and nationally important ecoregions with relatively intact aquatic systems.

Source: Thieme and others 2005.

antiscorbutica. Along the broad seasonal rivers, fringes of large riverine trees include the winter thorn (*Faidherbia albida*), natal mahogany (*Trichilia emetica*), acacia and waterberry (*Syzygium*). Because the riparian forests are extremely important to wildlife habitat and protect river banks from erosion, their conservation and economic value is high (Timberlake 2000).

The dambos are sinks for nutrients and are therefore areas of intense biological activity. The ancient floodplains have supported speciation in bulbous plants and woody "underground trees" (suffrutices) that have adapted to poor drainage and frequent frosts and fires by growing underground trunks. Such species, present in the Upper Zambezi floodplains or associated Kalahari sands, include the sand apple (*Parinari capensis*), *Annona stenophylla*, the legume *Cryptosepalum exfoliatum*, and *Trichilia quadrivalvis* (White 1976 in Timberlake 2000)

The ecoregion is understudied, and data on the biota are generally limited. Five fish species are thought to be endemic to the headwaters of this ecoregion: the ghost stonebasher (Paramormyrops jacksoni), cubango kneria (Parakneria fortuita), southern deepbody (Hypsopanchax jubbi), gorgeous barb (Barbus bellcrossi), and yangambi butterbarbel (Schilbe yangambianus). A second kneria (Kneria polli), and the stargazer mountain catfish (Amphilius uranoscopus) are also typical of these reaches. The Nile crocodile (Crocodylus niloticus) is to be found in the rivers, and two rare dragonfly species are near-endemic to the ecoregion.

Major conservation areas in the Zambezi Headwater ecoregion are the Kameia National Park, the Luiana Partial Reserve, and the Mavinga Partial Reserve in Angola; and, the Liuwa Plain National Park (which includes part of Luanginga River) and the West Lunga National Park (Lunga and Kabompo Rivers) in Zambia. The rivers are mostly undisturbed, with low population density, but farming and logging is expected to increase and intensify.

The Upper Zambezi Floodplains – ecoregion 16

The Upper Zambezi floodplain ecoregion contains floodplains, swamps, and lakes. The region begins at the confluence of the Lungúe Bungo, Zambezi, and Kabompo rivers and covers southwestern Zambia, southeastern Angola, the Caprivi Strip in Namibia, and the northern edge of Botswana. It extends through the Barotse Floodplain to the Victoria Falls. It is seen as nationally important, relatively intact, and has a conservation priority class of V.

This region is essentially a large, shallow, alluvial basin. Its gentle slopes and moderate rainfall have supported the development of extensive floodplains and swamps. These are maintained by frequent floods, which inundate the floodplains and swamps for long periods. The area acts as a large water storage facility that responds to floods by expansion and contraction of the water area rather than by significant rises and falls of the water level. The average flood height of the river is 5.2 meters. Extensive rapids are interspersed among the slow, swampy stretches, mainly between Nangweshi and Katima Mulilo, and Mombava to Victoria Falls. Gonye Falls, 300 kilometers upstream from Victoria Falls, is 21 meters—sufficiently high to constitute a barrier to the movement of fish in the dry season.

In the Upper Zambezi floodplain ecoregion, the Zambezi River receives water from the Cuando (also called Kwando or Mashi) and Lungúe Bungo rivers and—very rarely, in times of exceptionally high rainfall—from the Okavango system via the Chobe River. The Chobe can flow either way, depending on water levels in it and in the Zambezi River, facilitating interchange of biotas between the two systems.

Three major floodplains are highly important in terms of the ecoregion's biodiversity. The Barotse Floodplain extends from Lukulu to Nangweshi, and is 240 kilometers long, up to 35 kilometers wide, and has a flooded area of 7,500 km^2. The eastern Caprivi/southern Barotse Floodplain is located between Sesheke and Maramba and is 100 kilometers long. This is partly contiguous with the Chobe-Linyanti floodplain system, which begins where the Cuando River enters Botswana. The Chobe floodplain system is part of the southern Barotse Floodplain. The Linyanti swamp can expand to about 300 km^2 and floods in August, later than the upstream ones, due to the delaying effect of the *Phragmites-Typha-Cyperus* swamps in the river valley. Downstream of Linyanti swamp, Lake Liambezi has a water surface area of 100 km^2 when full, with 200 km^2 of bordering swamp vegetation. The total estimated areas of wetlands in this region are 250–1,000 km^2 of swamp and 1,670–1,870 km^2 of floodplain.

The wetlands support extensive and clearly defined flooded grasslands and swamp vegetation in the Barotse Floodplain, but these are intermixed with a mosaic of woodlands in the eastern Caprivi. Floodplain grass species in wetter areas include *Acroceras macrum*, *Brachiaria arrecta*, *Digitaria*, *Echinocloa pyramidalis*, and *Oryza longistaminata.* Deeper channels are dominated by the reed *Phragmitis mauritianus* along with stands of *Cyperus papyrus*, *Hibiscus diversiflius*, *Urena lobata*, *Persicaria senegalensis*, *Aeschynomne uniflora*, and the grasses *E. pyramidalis*, *E. stagnina*, and *Vossia cuspidate.*

The ecoregion provides rich breeding and feeding grounds for a rich set of fish species and herpetofauna, with a near-endemic radiation of large riverine cichlids. The floodplain fish migrate onto floodplains with the first floods in November through December to spawn. Juvenile fish benefit from the abundant food in the newly wetted and well-oxygenated conditions, in the shallow waters, and among vegetation that acts as a cover from predators. Fish communities are dominated by cyprinids, cichlids, and mochokid catfish, with a wide evolutionary radiation of cichlid species, including six *Serranochromis* species that eat snails, mussels, and crustaceans, and five *Sargochromis* predatory species. In terms of herpetofauna, the ecoregion is richer in species than the rest of the system, with the Barotse Floodplain supporting 89 species, including at least one frog endemic to the ecoregion, *Ptychadena mapacha*. Water birds also occur in large congregations, some breeding, with the Barotse Floodplain supporting more than 20,000 ruff (*Philomachus pugnax*), a non-breeding Palearctic migrant, 10,000 cattle egrets (*Bubulcus ibis*), and large populations of reed cormorant (*Phalacrocorax* *africanus*), open-billed stork (*Anastomus lemelligerus*), Caspian plover (*Charadrius asiaticus*), and whiskered tern (*Chlidonias hydridus*).

Threatened species include the wattled crane (*Grus caranculatus*, found in the Linyanti swamp, Liuwa plain, Barotse Floodplain, and Chobe-Linyati), the vulnerable slaty egret (*Egretta vinaceigula*), the Nile crocodile, the broadhead catfish (*Clariallabes platyprosopos*, found in Katima Mulilo), and the striped killifish (*Nothobranchius*, found in Gunkwe and Bunkalo). Mammals such as the red lechwe and sitatunga are now largely confined to protected areas; very little game has been spotted on the floodplains over the past 40 years (Turpie and others 1999).

Major protected and conservation areas include the Mamili National Park, the Liuwa Plain National Park, the Sioma Ngwezi National Park, and the West Zambezi Game Management Area.

The Kafue – ecoregion 8

This ecoregion of floodplains, swamps, and lakes extends over the Kafue system from central Zambia to its confluence with the Middle Zambezi. It is deemed nationally important, vulnerable, and with a priority status of V. It does not include the Kafue headwaters—parts of the Lufupa, Lunga, Luswishi, and upper Kafue—which are in Ecoregion 76. It contains the extensive, seasonally inundated floodplains of the Kafue Flats, which stretch 250 kilometers from the Itezhi Tezhi to the Kafue Gorge, and to the Lukanga swamp (a 260,000 hectare Ramsar site since 2005). These features earn the river recognition as a reservoir river, with floods stored on the extensive floodplains and released slowly back into the river. Inundation of floodplains occurs from January to June, when water depths average three meters and provide spawning and nursery areas for the abundant fish communities.

The seasonal flooding of the Kafue is the most important ecological process maintaining biodiversity in the region. Two of the 60 known fish species are endemic to the ecoregion. These are the killifish (*Nothobranchius kafuensis*) and the cyprinid (*Barbus altidorsalis*). Many of the other species do not have a much wider distribution than the flats. Largemouth bream, tilapias, and many small barbs migrate onto the floodplain to spawn, and at least one species, *N. kafuensis*, needs two concurrent wet seasons for eggs to hatch. Alien species that threaten the natural fish communities include *Oreochromis niloticus* and water hyacinth. A series of falls in the Kafue Gorge presents the main physical barrier to fish movement upstream from the Middle Zambezi. The ichthyofauna resembles that of the Okavango, Upper Zambezi, and Cunene Rivers. It also has some species in common with the Chambesi tributary of the Congo River, reflecting a history of suspected river capture of the Kafue by the Middle Zambezi and the Chambesi by the Luapula.

Large congregations of water birds, including the largest population of wattled crane in the region, use the flats for feeding and nesting. Other important species are the slaty egret, long-tailed cormorant (*Phalacrocorax africanus*), cattle egret (*Bubulcus ibis*), African open-billed stork (*Anastomus lamelligerus*), fulvous whistling duck (*Dendrocygna pratincola*), comb duck (*Sarkidiornis melanotos*), collared pratincole (*Glareola pratincola*), Caspian plover (*Charadrius asiaticus*), and ruff (*Philomachus pugnax*). Migratory mammals are a significant feature of the floodplains. About half of the remaining lechwe in Africa, *Kobus leche leche* and *K.l. kafuensis*, migrate here. *K.l. kafuensis* is endemic to Kafue Flats in the vicinity of the Kafue Gorge and the Itezhi Tezhi Dam (ITT).

Important protected areas include the Kafue National Park and associated Game Management Area, the Blue Lagoon National Park, the Lochinvar National Park (upstream of the Gorge), and parts of the Nampongwe River. The last two are part of the Kafue Flats Ramsar site (600,500 hectares since August 1991).

The Middle Zambezi Luangwa – ecoregion 69

This ecoregion, Savanna-Dry Forest Rivers, is defined by the Middle Zambezi and Luangwa Rivers and covers parts of Zambia, northern Zimbabwe, and western Mozambique. Along the Zambezi, the ecoregion extends from Victoria Falls to the Cahora Bassa Gorge and along the Luangwa River from its headwaters to the Zambezi confluence. It has a conservation status of endangered, with a priority conservation class IV. It is seen as a nationally important ecoregion. Both valleys are fertile compared to the nutrient-poor Upper Zambezi.

In the Middle Zambezi Luangwa ecoregion, the Zambezi flows through a series of gorges and narrow valleys and has been extensively modified by the reservoirs and the Kariba and Cahora Bassa dams. Floodplains and wetlands are limited, and the regulation of flow has reduced flood volumes, enhanced sedimentation in some places and erosion in others, and increased the extent of lake-like habitats, which has led to a changed composition of the fish communities. Specialized rock-loving species have declined or disappeared from some stretches of the river. Aquatic pest plants, such as water hyacinth and water lettuce, initially proliferated but are now less abundant. Dense beds of *Phragmites* reeds grow on previously bare sandbanks.

By contrast, the Luangwa River draining much of eastern Zambia is unregulated and pristine. In the dry season it is a slow-flowing river, meandering between sandy banks, but in the wet season its width spreads to several kilometers, filling ox-bow lakes and dambos, and flooding grassland. The Cahora Bassa reservoir has a high level of clay particles, which are carried in floods. Much of the Luangwa Valley is formally protected as national parks and game management areas.

The ecoregion as a whole supports the endangered marsh mongoose (*Herpestes palustris*), the African clawless otter (*Aonyx capensis*), the spotted-neck otter (*Lutra maculicollis*), and the hippopotamus (*Hippopotamus amphibius*). Species records are far from complete, but indicate the existence of 61 fishes, 49 amphibians, four reptiles (including the Nile crocodile), 27 mollusks, 18 dragonflies, 52 damselflies, three wetland butterflies, and about 700 bird species. Some parts of the system are extremely rich in species and wildlife diversity. The Luangwa River supports extensive populations of crocodiles and hippopotamus, as well as important populations of Thornicroft's giraffe (*Giraffa camelopardalis thornicrofti*), Cookson's wildebeest (*Connochaetes taurinus cooksoni*), and the water-dependent puku (*Kobus vardonnii*). Mana Pools, downstream of the Kariba Dam, supports crocodiles, 40 fish species, and more than 380 bird species. It is also an important staging post for migratory water birds such as Lilian's lovebird (*Agapornis lilianae*).

In the Luangwa Valley, important bird species that feed in the receding floodwaters include the yellow-billed stork (*Mycteria ibis*), open-billed stork (*Anastomus lamelligerus*), white pelican (*Pelecanus onocrotalus*), great white egret (*Egreeta alba*), and goliath heron (*Ardea goliath*). Salt pans support large flocks of southern crowned cranes (*Balearica regulorum*), and flooded mopane woodlands are used for breeding by tens of thousands of knob-billed (*Sarkidiornis melanotos*) and white-faced (*Dendrocygna viduata*) ducks. Palearctic and intra-African migrants abound in the warm rainy season southern carmine bee-eaters (*Merops nubicoides*) nest in the sandy river banks, and the eastern population of white stork (*Ciconia ciconia*) use the valley as a major overwintering ground.

The Luangwa Floodplain is a Ramsar site since February 2007 and covers an area of 250,000 hectares.

The Zambezian Highveld/Plateau – ecoregion 78

The Zambezi Plateau is a high-altitude, cool ecoregion classified as a savanna-dry forest rivers ecosystem. It is seen as nationally important and critically endangered, with a priority conservation class of IV. The ecoregion is contained in Zimbabwe and includes highlands streams and headwaters of some Zambezi tributaries (including the Lundi, Pungwe, Manyame, and Mazowe) as well as the Save River in the east. The area is characterized by large and small rivers, dambos, artificial reservoirs, and a few floodplains. The perennially waterlogged dambos are widespread, with a total area of about 12,000 km^2, and provide dry-season flow to the streams. Prominent wetlands are the perennial cluster of pools in the Lundi River Valley known as Chipinda Pools and the 40 km^2 Save-Runde Floodplain, including the Tamboharta Pan, in the southeast part of the ecoregion, which is largely devoid of floodplains. Both wetlands provide watering areas for large mammals and are rich in bird life.

The ecoregion has no known endemic species. Mammals include the March mongoose, African clawless otter, and hippopotamus. Species records exist for 39 fishes, 38 amphibians, eight reptiles, 17 mollusks, and one wetland butterfly species. The rivers, including the Pungwe and Save, appear to be impoverished in fish species, while the dambos support more than 100 species of vascular plants including eight that are endemic.

One of the ecoregion's important protected areas is the Gonarzhou National Park (Chipinda Pools).

The Lower Zambezi – ecoregion 66

The Lower Zambezi is also an ecoregion classified as a savanna-dry forest rivers ecosystem. It is seen as nationally important and endangered, with a priority conservation class of IV. It stretches from the Cahora Bassa Dam to the coast, encompassing the Lower Shire River and falling mostly in Mozambique. Downstream of the Cahora Bassa Dam to the Lupata Gorge and 70 kilometers downstream of Tete, the Zambezi is mostly contained within a clearly defined channel. From below the gorge to the sea, the channel becomes wider, with many anastomosing channels and shifting sandbanks. Downstream of the Shire-Zambezi confluence, it forms a large deltaic floodplain system. The delta proper is generally seen as starting at Mopeia, about 120 kilometers from the coast, where the Rio Cuacula splits and flows east toward Quelimane while the main stream flows southeast.

The delta as a whole is a mixture of woodlands, savanna, mangroves, and coastal dunes, with a complex mosaic of wetlands. The southern portion, around Marromeu, is a wetland area of significant biodiversity importance, with extensive areas of lagoons, papyrus, aquatic grasslands, and mangroves. Much of the sediment load historically moving through the system and onto the floodplains is now trapped by the Kariba and Cahora Bassa dams. The Shire River is now the major contributor to floodplain sediments. As a result, channel morphology is changing downstream (Davies, Beilfuss, and Thoms 2000), and the coastal zone is eroding, causing the loss of coastal mangroves.

Biologically, the ecoregion is a crossroads between the Middle Zambezi, the eastern coastal rivers, the Malawi region, and brackish and marine species. Freshwater species estimates for the ecoregion include 94 fishes (mostly floodplain dwellers), 73 water birds, 19–28 amphibians, several reptiles, 221 mollusks, 25 dragonflies, and 84 wetland plant species. The Lower Shire has 63 fish species recorded, five typical of the Lake Malawi/Niassa/Nyasa ecoregion and not occurring in the rest of the Lower Zambezi. A lower Shire tributary, the Ruo, has a unique relict fish species above the Zoa Falls, the only known to be endemic to this ecoregion. The reptiles include the hinged terrapin (*Pelusios castanoides*), the Nile monitor (*Varanus niloticus*), and the Nile crocodile. The area is recognized as being inadequately studied.

The Delta supports water bird species of global concern, such as the wattled crane and African skimmer (*Rynchops flavirostris*), the last of which has suffered from the loss of sandy nesting sites. Large breeding colonies of white pelicans, storks, and herons are found there. As a result of the harnessing of floods by upstream dams and consequent dewatering of floodplains and reduction of sediment-maintained habitats, however, numbers have dropped over the past 30 years.

Important protected areas include the Marromeu Buffalo Reserve, an area of floodplain grasslands and a 688,000-hectare Ramsar wetland site since 2004. In addition, the 17,000-hectare Nhapakwe Forest Reserve is outside the actual wetland. There are also three hunting concessions covering a total of 528,000 hectares, much of which is in the wetlands.

The Lake Malawi/Niassa/Nyasa – ecoregion 53

Lake Malawi/Niassa/Nyasa is an ecoregion defined by the drainage basin of Lake Malawi/Niassa/Nyasa. It is classified as a large lake ecoregion, globally outstanding, and vulnerable; it has the highest priority classification of I. The lake is the southernmost of the deep-water lakes of the East African Rift Valley and the only natural large lake in the Basin (Timberlake 2000).

Lake Malawi/Niassa/Nyasa is the ninth-largest lake in the world and the fourth-deepest, with a surface area of about 29,000 km^2. More than 200 rivers flow into Lake Malawi/Niassa/Nyasa, most of them ephemeral and the outflowing Shire River passes through Lake Malombe on its way south to drain into the Lower Zambezi. The Kapichira cataract within Murchison Falls on the Lower Shire forms an absolute physical barrier to upstream movement of fish species, isolating the lake from the rest of the Zambezi system.

The area is one of outstanding biodiversity, supporting one of the richest sets of lake fish species in the world. Ninety-nine percent of the more than 800 cichlid fish species and more than 70 percent of the 17 clariids are endemic to the ecoregion; it is thought that there may be as many as 3,000 fish species or recognizably different populations in the lake. This endemism is likely reflected in other fauna, such as aquatic invertebrates, and also generally in the area's 200 mammals; 650 birds; 30 mollusks; and 5,500 plant species.

Important protected areas include the Lake Malawi/Niassa/Nyasa National Park, part of which is a World Heritage site; the Liwonde National Park, which encompasses a small part of Lake Malombe; the Nkotakota National Park, which protects much of the Bua River catchments; the Lenwe National Park, which is adjacent to Elephant Marsh; and, the Majete Game Reserve.

The Mulanje – ecoregion 43

Mulanje is an ecoregion with highland and mountain ecosystems. It is nationally important and endangered, with a conservation priority of IV. It is named after the Mulanje Massif, a large isolated mountain massif in southeastern Malawi. Headwaters rising on the massif and flowing south form the Ruo River, which flows into the Shire River and ultimately the Lower Zambezi.

Those southern headwater streams are isolated from downstream reaches of the Shire-Zambezi system by waterfalls of up to 200 meters, including Zoa Falls on the Ruo River. They support many relict and endemic species and fish species that, overall, have major differences from those of nearby river systems. Relict fish species include *Hippopotamyrus ansorgii*, *Barbus eutaenia*, *B. lineomaculatus*, and *Opsaridium zamezense*. The biodiversity of other faunal groups and the flora is thought to be high. Out of 30 known amphibians, two species are endemic and two near-endemic; records exist of 22 dragonfly species.

One of the ecoregion's important protected areas is the Mulanje Mountain Forest Reserve.

2.4.3 Conclusion

From a continental perspective, there are four areas of particularly outstanding and biodiversity importance in the Basin. These are:

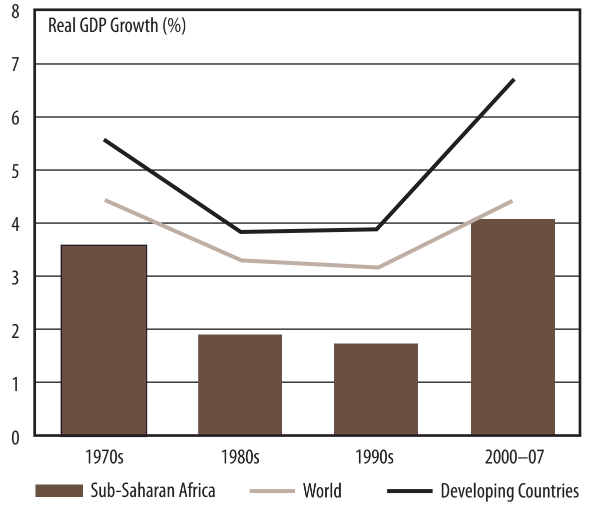
- Lake Malawi/Niassa/Nyasa, which is a region of global conservation importance because of the evolutionary radiation of fish groups and some other aquatic groups.
- The swamps, floodplains, and woodlands of the pale-Upper Zambezi in Zambia and northern Botswana, including the areas of Barotseland, Busangu, Kafue, Okavango, and Bangweulu, which together are thought to be areas of evolutionary radiation for groups as disparate as the Reduncine antelope, suffrutices, and bulbous plants. The meeting of three centers of distribution in the Barotse area has led to it supporting very rich reptile and amphibian communities. The floodplains, dambos, and grasslands of this area are some of the most extensive and least disturbed on the African continent and have an extremely high conservation value.
- The Middle Zambezi Valley in northern Zimbabwe and the Luangwa Valley in eastern Zambia, which are not necessarily areas of high biodiversity or endemism, but are two of the last remaining protected areas extensive enough to support large populations of large mammals.
- The Gorongosa/Cheringoma/Zambezi Delta area of central Mozambique, which covers an area of enormous habitat diversity not found in such close proximity elsewhere on the continent (Tinley 1977 in Timberlake 2000).

Each of these areas are vulnerable to and threatened by development activities in the Basin, such as land clearance for agriculture, overharvesting of natural resources, damming of rivers, and the introduction of alien aquatic species.

2.5 MACROECONOMIC OVERVIEW

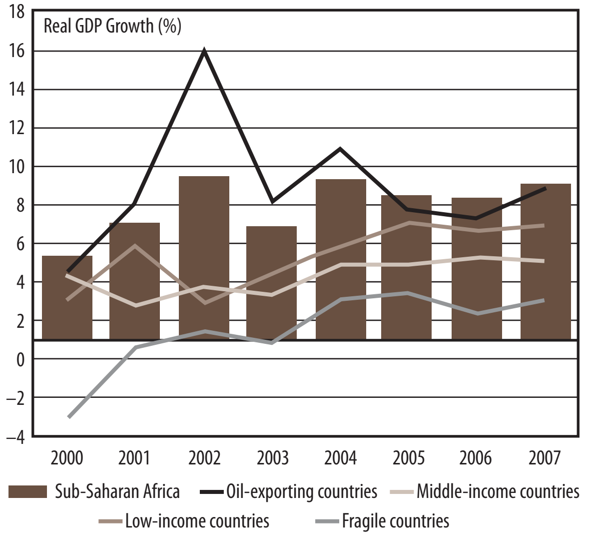
Sub-Saharan Africa has experienced steady growth over an extended period. In 2007, growth was the

Figure 2.20. Global GDP trends (1970–2007)



Sources: IMF, *World Economic Outlook*; and IMF, African Department database.

Figure 2.21. GDP trends in Sub-Saharan Africa (2000–2007)



Sources: IMF, *World Economic Outlook*; and IMF, African Department database.

highest in a decade, reaching 6.5 percent of gross domestic product (GDP) in real terms (IMF 2008).

Growth is being driven largely by domestic demand, but also by increased domestic investments and higher government spending as a result of higher oil revenues and debt relief. According to the IMF, sound macroeconomic policies have improved both oil revenue savings and general business environments, which in turn have reduced vulnerability to external shocks. Inflation remains low for most countries, and current account deficits have been restrained. The G8 commitment of doubling aid to Africa is not on track despite increased allocations. China is also stepping up assistance to the region. Private capital flows to Sub-Saharan Africa reached $50 billion in 2007, and although still dwarfed by global figures ($6.4 trillion in 2006), they overtook foreign aid for the first time. Although most was directed toward Nigeria and South Africa, a number of other countries including Ghana, Uganda, and Zambia have also benefitted. Banking systems are improving, although the sector suffers from lack of depth and efficiency.

The ZRB is rich in natural resources. The key economic activities are fishery, mining, agriculture, tourism, and manufacturing. Industries in the riparian countries are highly dependent on electricity produced by hydropower plants in the Basin, and to a lesser extent on coal and oil.

The economies of the riparian countries can be broadly characterized as fast-growing with high income generation (centered on extraction of mineral resources such as diamonds, oil, copper, and cobalt). At the same time, they have very high rates of poverty with low levels of basic service coverage (table 2.7.).

The global economic crisis has had a significant effect on growth rates. Between 2007 and 2009 all countries except Zimbabwe experienced a significant drop in GDP growth rates. Nevertheless, IMF estimates indicate that a recovery is underway, with increasing GDP growth rates in all countries except Malawi (table 2.8.).

2.5.1 Angola

Since 2001 several production sectors—oil, diamonds, manufacturing, construction, processing, and services—have experienced steady growth. Real GDP growth reached 18.6 percent in 2006, driven primarily by oil and diamond extraction.[2]

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[2] Quoted from IMF 2007a.

Table 2.7. Macroeconomic data of Zambezi riparian countries (2006)

Summary data 2006	Population '000	GDP $ million	GDP/cap	Inflation %	Current account % of GDP
Angola	15,864	45,167	2,847	12.2	23.3
Botswana	1,574	11,048	7,019	7.1	17.6
Malawi	13,122	3,164	241	8.1	–6.2
Mozambique	20,041	6,776	338	7.9	19.7
Namibia	2,048	6,941	3,389	6.7	15.9
Tanzania	38,200	14,198	372	7.0	–7.8
Zambia	11,873	10,893	917	10.7	1.1
Zimbabwe	11,732	1,437	122	10,452.0	–6.0

Source: IMF 2008.

Table 2.8. GDP change in constant prices (2007–2014)

Country	2007	2008	2009	2010	2011	2012	2013	2014	Estimates start after
Angola	20.3	13.2	0.2	9.3	8.4	5.4	6.5	6.1	2006
Botswana	4.4	2.9	–10.3	4.1	8.5	13.8	8.9	2.1	2008
Malawi	8.6	9.7	5.9	4.6	3.2	3.2	3.2	3.3	2007
Mozambique	7.0	6.8	4.3	5.2	6.0	6.2	6.5	6.5	2008
Namibia	5.5	2.9	–0.7	1.7	2.2	2.7	3.0	3.0	2007
Tanzania	7.1	7.4	5.0	5.6	6.7	7.5	7.5	7.5	2007
Zambia	6.3	5.8	4.5	5.0	5.5	6.0	6.1	6.1	2008
Zimbabwe	–6.9	–14.1	3.7	6.0	6.0	6.0	6.0	6.0	2007

Source: IMF 2009a.

Agricultural production is deemed to have high potential in fostering diversification and further growth in the economy (presently eight percent of GDP). Inflation fell from 19 percent to 12 percent during 2006. The nominal exchange rate held steady throughout 2006 while the real exchange rate appreciated by about six percent. The fiscal balance has shifted to surplus (reaching 15 percent of GDP in 2006 against a six percent deficit in the budget), but Angola has saved a smaller portion of its oil windfall than most other African oil producers. The external current account surplus widened to 23 percent of GDP in 2006, and official reserves doubled and reached $8.5 billion, equivalent to about four months of imports of goods and services. The external debt-to-GDP ratio declined from 40 percent to 20 percent between 2005 and 2006. Angola's most successful initiative in public financial management (PFM) and fiscal transparency continues to be the Sistema Integrado de Gestão Financeira do Estado (SIGFE) (Integrated Financial Management System). It covers all provinces and will be extended in 2007 to include some autonomous bodies and new modules. The SIGFE has strengthened budget execution and reporting and information sharing. In the private sector, however, the investment climate needs improvement.

Despite positive macroeconomic trends in Angola, poverty remains deeply entrenched. Approximately 70 percent of the population live on less than $2 per day, and the majority lack access to basic health care and services. Though infant mortality has fallen, it is still high at 15.8 percent. Likewise, maternal mortality of 1,800 per 100,000 births is one of the highest in Sub-Saharan Africa. Approximately half the population lack access to safe drinking water and sanitation, which is a political priority. The HIV/AIDS infection rate is comparably low at 3.9 percent. Primary school enrollment is very low—56 percent—and literacy skills need strengthening, particularly among women.

2.5.2 Botswana

At independence in 1966, Botswana was one of the poorest countries in the world. Over the past 40 years, Botswana has grown at an average rate of 8.6 percent per year, one of the fastest growth rates in the world. As a result, it is now an upper-middle-income country. The economy's dependence on natural resources exports has given rise to the "Dutch disease" effect however, although severe symptoms have been prevented by good policies and institutions (for example, Botswana is the largest exporter of diamonds, which account for 80 percent of exports but only five percent of employment). Manufacturing's share of GDP has declined modestly over time, reaching around four percent of GDP in 2005. The sector has shrunk relative to other growing sectors but not in absolute terms. Since the SACU revenues are likely to decline further, public finances are highly vulnerable.

Despite economic growth, Botswana's human development indicators do not compare favorably with similar countries. Thirty-one percent of the population live in extreme poverty, and Botswana has been hard hit by the HIV/AIDS epidemic with an infection rate of 17.1 percent (2004).

2.5.3 Malawi

Since 1999 Malawi's macroeconomic performance has been characterized by the rapid increase of domestic debt. High interest rates compromised the government's ability to allocate resources for critical poverty alleviating initiatives. Reforms were implemented in 2004. Interest payments on domestic debt remain a key priority in pursuit of macroeconomic stability and will generate fiscal space needed to increase other government expenditures. Certain key challenges remain. Growth must be accompanied by improved economic management capacity. Managing potential scaling up of external aid is vital, as is the ability to attract higher levels of external private and public capital flows. Malawi's agricultural production constitutes more than 40 percent of the economy. As a result, weather patterns deeply affect agricultural production and GDP. Weak fiscal performance between 1999–00 and 2003–04 brought the country to the verge of a financial crisis. As official development assistance (ODA) decreased, the large fiscal deficits of more than seven percent of GDP were financed largely by domestic borrowing. Consequently, debt increased sharply from less than three percent to 25 percent between 1999–00 to and 2003–04. Interest rates rose, and as a result, the government's domestic interest bill shot up to a massive 9.2 percent in 2003–04. Since 2004, strict fiscal discipline led to improved performance. Inflation declined, donor budget support increased, and debt fell to 20 percent of GDP in 2005–06. Despite the impact of the severe food crisis in 2005, the Reserve Bank has gradually reduced the nominal discount rate from 45 to 20 percent between 2003 and 2006. Private investment has increased to 3.7 percent of GDP, and interest rates have declined. Malawi reached the HIPC completion point in August 2006 and subsequently qualified for the Multilateral Debt Relief Initiative (MDRI). This resulted in a decline of Malawi's debt-to exports ratio from 229 percent to 32 percent. Malawi's fitch credit rating has also been upgraded from CCC to B– raising prospects for private capital inflows.

Though the macroeconomic situation remains fragile, economic prospects are positive. Growth is projected to remain above historical levels, and inflation is expected to fall to single digits. Malawi is especially vulnerable to weather-related shocks that cause crises in food production and security. Moreover, delays in projected external financing and rising expenditure pressures could weaken expenditure control.

2.5.4 Mozambique

Prior to independence in 1975, economic activity and land ownership was dominated by colonial entrepreneurs and farmers. With their departure, Mozambique experienced a number of structural constraints: limited capacity in the private sector, high levels of unemployment, weak public institutions, heavy dependence on foreign aid, and an economy on the verge of collapse. The new government introduced strong state control of the economy to sustain agricultural development. Political unrest led to a debilitating civil war. With peace in 1992, an influx of millions of refugees and displaced persons back into their home areas created both opportunities for agricultural growth and new challenges. In 2003, the government's budget deficit increased to four percent of GDP, while total revenue rose slightly to 14.3 percent of GDP and current expenditure remained unchanged at 16 percent of GDP. Tax receipts increased substantially. Substantial debt relief and a commitment to strengthening the financial system have fostered competitiveness and expanded financial services to the poor. Strengthened governance and the judicial system are meant to help private sector development, sustain strong economic growth, and reduce poverty.

Mozambique's overall macroeconomic performance has been more resilient to the global economic crisis than anticipated. There have been large declines in export receipts, private capital inflows, and project aid. But, the government has responded promptly and mitigated the impact by easing macroeconomic policies and containing the spillover effects to the domestic economy. The emerging rebound of global economic activity and the anticipated recovery of international credit markets have given some rise for optimism.

Measures to mobilize revenue collection play an important role in consolidating fiscal and macroeconomic stability. The government will continue to push for improved efficiency in the tax system. This includes simplifying the tax system for small- and medium-sized enterprises, providing a new code for tax benefits, and computerizing the entire chain of revenue collection. The government is committed to implementing an improved system for budget execution, control, and evaluation called e-Sistafe. Debt rescheduling agreements with bilateral creditors under the HIPC initiative continue to be a priority.

2.5.5 Namibia

Namibia, a lower-middle-income country, has a small, open economy intimately linked with South Africa. The currency is pegged to the South African rand. Steady growth of 4.3 percent, moderate inflation, strong external surpluses, and low indebtedness has characterized the economy over recent years. This is largely the result of prudent fiscal policies, a stable political environment, developed infrastructure, and strong legal and regulatory instruments. Recent volatility in growth is chiefly due to spurts in diamond production in 2004 and 2006. The economy is dominated by the public and private service sectors, accounting for around 60 percent of overall output. The share of the mining sector peaked at 14 percent of GDP in 2002 and has averaged about nine percent since. The share of secondary sectors, in particular manufacturing, has remained virtually unchanged and their contribution to growth is modest. Constraints in labor capacity, insufficient technological advancements, limited domestic investments, and dependency on the South African economy have limited the success of efforts to diversify the economy.

Through its membership in the Common Monetary Area, Namibia is linked to South Africa's inflation targeting framework meaning inflation trends in Namibia follow the South African rates closely. Average annual inflation fell from 11.3 percent to 2.3 percent between 2002 and 2005, but rose again to five percent in 2006. Fiscal policy is the only macroeconomic policy instrument available to Namibia, and its fiscal situation has recently strengthened significantly. The deficit dropped from 7.5 percent of GDP in 2003–04 to an estimated 0.7 percent in 2005–06 due to effective revenue collection, a windfall in revenues from the South African Customs Union (SACU), and decline in spending. Exports account for almost 40 percent of GDP, with diamonds and other minerals accounting for close to 60 percent of total exports. Namibia's manufactured exports, mainly processed meat products (beef, small stock, and game) and processed fish and lobster, go to the European Union (EU), U.S., and Japanese markets. Imports consist predominantly of consumption items and capital goods, mostly from South Africa. Namibia's trade deficit of about six percent of GDP since 2002 has been offset by high customs revenue transfers and positive net balances from services and income accounts. The positive current account balance has been accompanied by persistent large capital outflows, however, as financial institutions invest heavily in South Africa. This has kept reserves at low levels. In 2004–05, public debt stood at 33.8 percent of GDP but has since dropped and was an estimated 19.1 percent in 2009,[3] below the government's target of 25 percent and lower than that of most other Sub-Saharan African countries.

Macroeconomic stability is overshadowed by three issues: high levels of poverty, high unemployment, and unequal distribution of wealth. The gini-coefficient in Namibia is amongst the highest in the world at 0.6. While the number of people living in poverty has declined since independence, it remains high at 27 percent.[4] Unemployment affects nearly a third of the labor force and is especially prevalent among those lacking required professional skills.

2.5.6 Tanzania

Tanzania launched a series of broad-based, macroeconomic management reforms in 1986, which stimulated economic growth and promoted stability that continues to the present. Agriculture plays a fundamental role in the economy; however, recent growth derives from increased cropped area. To encumber detrimental clearing of primary forest for this purpose, future growth in agriculture must come from efficiency gains in production, processing, and marketing. Despite global and regional headwinds, economic growth reached 7.5 percent in 2007–08, fuelled by expansion of manufacturing, construction, and services. This has slowed somewhat since then but remains positive. With growth in domestic revenues and public spending in line with the budget, strengthened monetary policies have been vital. Interest rates have declined sharply, although inflation remains above the Bank of Tanzania's target, reflecting pressures from global fuel and food prices. Tanzania faces two main challenges to ensure continued growth and stability. First, monetary policy will need to strive to return inflation to its target level. Second, the state budget will need to balance the significant demands on public resources for Tanzania's second-generation growth and poverty reduction strategy (MKUKUTA) priorities, including agricultural development, education, health, and infrastructure.

Both rural and urban poverty have declined in Tanzania. Yet 17 million—almost half of the population of 37 million—still live below the poverty line. Between 1995 and 2005, malnutrition prevalence declined from 25 to 17 percent. Decline in rates of poverty was most rapid in Dar es Salaam and least rapid in rural areas. Enrollment in primary schools has been higher in urban than in rural areas, and a quarter of adults do not have formal education.

2.5.7 Zambia

Between 1991 and 1998, real GDP fell by an average of 0.2 percent per year in Zambia. With sound management and economic growth, the government has dealt with the challenges of low commodity prices and ineffective policies. Economic growth has been strong since 2000 with a GDP growth rate averaging five percent. This is particularly due to the expansion of the mining, construction, and services sectors. Agricultural growth has remained stagnant, however, which is due in part to low-value commodity production in smallholder agriculture. Increased copper production and a 300 percent price rise since 2003, along with additional debt relief through the HIPC and MDRI initiatives, which together have reduced external debt to 10 percent of GDP in 2007, have improved Zambia's external position significantly. The current account balance has thus shifted from negative 4.4 percent of GDP in 2005 to a positive balance of three percent in 2006. Much-needed international reserves have since grown and now equate to 2.5 months of imports. Non-copper exports have also grown rapidly, amounting to $880 million in 2006. Even though the kwacha depreciated due to appreciating exchange rates, its level in real terms has recently been 40 percent above the average level for the period 2003–04. After years of weak fiscal policy implementation, the authorities have improved management of fiscal resources and reduced domestic financing needs drastically. The overall deficit for 2007 declined to 0.2 percent of GDP, driven in part by low capacity in line ministries to execute capital

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[3] CIA Fact book: https://www.cia.gov/library/publications/the-world-factbook/geos/wa.html.

[4] A household is considered poor if it spends 60 percent or more of its income on food (IBRD 2007).

projects. The deficit increased to 2.1 percent in 2008 and is expected to remain at that level for 2009 and 2010.[5] Tight monetary policy, a strong currency, and lower food prices due to a recovery in food production after a drought during the 2004–05 planting season, have reduced inflation to single digits for the first time in over three decades. In October 2009, inflation stood at five percent. In this economic context, loans and advances by commercial banks to the private sector have expanded rapidly (10.4 percent of GDP in 2007). Further growth will require addressing structural constraints and the adverse impact of large resource inflows, improved and transparent public sector performance, and improved competitiveness.

Increasing agricultural productivity, with diversification of higher-value crops, enhanced commercialization among smallholders, and expansion of agroprocessing, as well as connectivity and integration of the rural economy, will be important to improve economic opportunities for the rural population.

2.5.8 Zimbabwe

With an abundance of fertile land and natural resources, including wildlife and minerals, Zimbabwe was once the breadbasket of southern Africa. Since the late 1990s, the country has suffered from political crisis and economic and social regression, accentuated by sharp decline in developmental assistance and frequent droughts. Between 1999 and 2006, GDP declined by 35 percent and unsustainable external debt reached $4.7 billion. Despite relatively strong revenue collection, the IMF estimates that the adjusted fiscal deficit, including the quasi-fiscal activities of the Reserve Bank of Zimbabwe (RBZ) to support loss-making parastatal and other strategic sectors, reached over 80 percent of GDP in 2006. Large parts of the public sector financing needs were met through money creation, fuelling monetary expansion and a sharp rise in inflation. In February 2007 it reached a record high of 1,730 percent. The current account deficit has deteriorated steadily over the past five years, due largely to the collapse of agricultural exports. Though it was partly compensated by increases in mining exports on account of higher world prices, the volume of recorded mining exports fell in recent years due in part to smuggling. Imports have been compressed, constraining the supply of essential inputs for production. Since 2008, the government made efforts to build international reserves, but this was accomplished by the accumulation of external arrears.

The poverty rate increased from 25 to 63 percent between 1990 and 2003. Despite recent decreases, the HIV/AIDS prevalence rate one of the highest in the world at 18 percent. In addition, brain drain has constrained the country’s capacity to recover from ongoing economic and social crises.

2.6 SOCIOECONOMIC OVERVIEW

An assessment of the sociological context of the Zambezi River Basin, calls for analysis of key aspects of rural and urban life: demographic development, income and poverty, livelihood, gender and youth, and health and education.[6] For each, the analysis is divided according to the upper, middle, and lower parts of the Basin.

The Basin population of around 30 million is unevenly distributed (table 1.2.). More than 85 percent live in three countries (Malawi, Zimbabwe, and Zambia) and across four subbasins: Kafue, Kariba, Tete, and the Shire River and Lake Malawi/Niassa/Nyasa. Approximately 75 percent of the Basin population live in rural areas, while the remaining 25 percent live in 21 major towns. The rural-urban divide differs among the riparian countries, from 50 percent in Zambia to around 85 percent in Malawi.

2.6.1 The Upper, Middle, and Lower Zambezi River Basin

Sociological indicators and statistics are presented for the major three subdivisions of the ZRB: the Upper, Middle, and Lower ZRB.

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[5] http://www.africaneconomicoutlook.org/en/countries/southern-africa/zambia.

[6] This description builds on existing sources. This has made cross-national comparisons of poverty measurements difficult, with different definitions of absolute and relative poverty being applied. Therefore the general term poverty refers to the national use of this term. In many cases it has not been possible to obtain data specific to the parts of a country within the Basin, and thus descriptions are limited to national or administrative borders and not watersheds.

Table 2.9. Select human development indicators

Indicator	Angola	Botswana	Namibia	Malawi	Mozambique	Tanzania	Zambia	Zimbabwe
Poverty headcount ratio at $1.25 a day (PPP) (% of population)	54% (2000)	31% (1995)	49% (1995)	74% (2005)	75% (2005)	89% (2000)	64% (2005)	n/a
Gini co-efficient	33.0 (2005)	n/a	n/a	39.0 (2004)	47.1 (2003)	n/a	50.7 (2007)	n/a
Mortality rate, infant (per 1,000 live births)	116 (2008)	35 (2005)	55 (2005)	80 (2005)	119 (2005)	78 (2005)	105 (2005)	65 (2005)
Maternal mortality ratio (modeled estimate, per 100,000 live births)	1400 (2005)	380 (2005)	210 (2005)	1100 (2005)	520 (2005)	950 (2005)	830 (2005)	880 (2005)
Improved water source (% of population with access)	51% (2008)	95% (2000)	81% (2000)	76% (2005)	41% (2000)	53% (2000)	54% (2000)	80% (2000)
Prevalence of HIV, total (% of population ages 15–49)	2.1% (2008)	24.9% (2005)	15.3% (2005)	12.3% (2005)	12.2% (2005)	6.4% (2005)	15% (2005)	19% (2005)
Total enrollment, primary education (%)	53% (2000)	84% (2005)	85% (2005)	93% (2005)	77% (2005)	93% (2005)	93% (2005)	84% (2000)
Life expectancy at birth, total (years)	47 (2008)	49 (2005)	52 (2005)	47 (2005)	43 (2005)	56 (2008)	46 (2008)	45 (2008)

Source: World Development Indicators Database.

The Upper ZRB covers eastern parts of Angola,[7] small parts of northeastern Namibia (Caprivi), northern Botswana (Chobe District), and western and northwestern parts of Zambia. Apart from highlands in Angola and some relatively productive parts of northeastern Zambia, the Upper Basin is dominated by the sands of the Kalahari and the floodplains and dambos along the river and in the Barotse Floodplains. This Upper Basin corresponds to the following subbasins considered in the study: Kabompo, Upper Zambezi, Lungúe Bungo, Luanginga, Barotse, and Cuando/Chobe.

The Middle ZRB covers a majority of Zambia, considerable parts of Zimbabwe, and borders with eastern Botswana and Namibia. The Copperbelt, Central, Southern, and Lusaka Provinces in Zambia fall entirely within the Middle Basin, as do smaller parts of the Northwestern and Eastern provinces. In Zimbabwe, north Matabeleland, the Midlands, and west Mashonaland fall within this part of the Basin. The Middle Basin corresponds to the subbasins of Kariba, Kafue, Luangwa, and Mupata.

The Lower ZRB covers all of Malawi, a small strip of southern Tanzania along the eastern coast of the Malawi River, northeastern and central parts of Mozambique, and parts of northeastern Zimbabwe. It corresponds to the subbasins of Shire River and Lake Malawi/Niassa/Nyasa, Tete, and Zambezi Delta.

2.6.2 Demographic development

The Upper ZRB is sparsely populated with the exception of the Angolan highlands. Population density is generally higher along the river and near the floodplains and dambos due to the relatively high potential for diverse use of natural resources. The population density for the Barotse Floodplains, for example, is 34 persons per km^2 (Turpie and others 1999). In Zambia, the people living in the Western and Northwestern provinces constitute eight and six percent of the total population respectively. The rural populations, which depend primarily on subsistence farming, make up 86 and 85 percent of the provinces' population respectively; these totals

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[7] Mainly Moxico, Huila, Huambo, and Cuanza Sul Provinces.

Table 2.10. Macroeconomic overview

Indicator	Angola	Botswana	Malawi	Mozambique	Namibia	Tanzania	Zambia	Zimbabwe
Population (in millions)	16.4 (2006)	1.8 (2006)	13.2 (2006)	20.1	2.1 (2006)	39.5	11.9	13.6
Population growth (%/year)	2.8%	1.3%	2.2%	2.0%	1.3%	2.6%	1.8%	0.6%
labor force growth (%/year)	2.9%	–0.3%	2.0%	1.6%	1.3%	2.4%	1.7%	1.5%
Prevalence of HIV, total (% of population ages 15–49)	3.7%	24.1%	14.1%	16.1%	19.6%	6.5%	17.0%	20.1%
Macroeconomic trends	• Strong economic performance • Increase of oil production of around 13% • Increase of agricultural value of 8% • Inflation fell from 19% to 12% in 2006 • Medium term outlook is positive; GDP is expected to grow about 25% on average in the next two years and about 8% average in 2009–10 driven by the oil sector • Fiscal deficit is projected to be sustainable in the medium and longer term	• Economy is dominated by the diamond industry • GDP growth over the past years established around 5%; this trend is expected to continue in the medium–term • Major challenge is diversification of the economy and identification of other engines of growth as the diamond market begins to taper off	• Relatively small economy • Agriculture is the mainstay, but vulnerable to weather shocks • Unequal land distribution Over 40% of smallholders households cultivate less than 0.5 hectares • Export is dominated by tobacco, tea, cotton, coffee and sugar • Improvement of macroeconomic performances	• Export commodities: aluminum, cashews, prawns, cotton, sugar, citrus, timber, bulk electricity, natural gas.	• Middle income country • Among top 10 countries worldwide in share of GDP spent on education • The generally good growth and macroeconomic picture is overshadowed by the lingering levels of poverty; high unemployment; and unequal distribution of wealth and income	• Strong growth over a number of years • Inflation under control • Economic performances continue to be strong, despite the drought of 2006 • Poverty still high 45% under poverty line • Agriculture very important	• Negative impact on economy by macroeconomic instability, resolved with debt cancellation. • Income between 1974 and 1990 fell by 5% • In 2002 Zambia was hit by a copper crisis and a severe drought • Mining constrained by power supply	• Economic growth was strong during the decade after independence, but in the late 1990 the growth began to slow • In 2002, Zimbabwe's economy was severely constrained • Overvalued exchange rate • Unsustainable external debt burden • Inflation in 2006 more than 1,000% • Adjusted fiscal position extremely poor (–25% of GDP)

Continued on next page

Table 2.10. Macroeconomic overview *(continued)*

Indicator	Angola	Botswana	Malawi	Mozambique	Namibia	Tanzania	Zambia	Zimbabwe
GDP 2006	• $45.2 billion • 18.6% annual growth • 69.7% industry • 21.4% service • 8.9% agriculture • Projection 2007 31%	• $10.6 billion • 53.1 % industry (38% accounts to diamond mining industry) • 44.9% services • 2% agriculture	• $2.2 billion • 10.9% annual growth rate • 44.7% services • 19.8% industry • 35.5% agriculture	• $7.6 billion • 8.5% annual growth rate • 49.3% services • 29.0% industry • 21.7% agriculture	• $6.4 billion • 4.6% annual growth • 57.7% services • 31.0% industry • 11.3% agriculture	• $12.8 billion • 6.7% annual growth rate • 37.3% services • 17.4 % industry • 45.3% agriculture	• $10.9 billion • 6.0% annual growth rate • 59.2% services • 24.8% industry • 16.1% agriculture	• $5.0 billion • –4.8% annual growth • 50.7% services • 27.4% industry • 21.9 % agriculture
Growth Indicators	GDP 2008–10: 7.5% GDP per capita: 13.9%	GDP: 2008: 6.0% 2009: 3.8% 2010: 5.5% GDP per capita: 3.6%	GDP 2006–10: 5.8% GDP per capita: 2.7%	GDP: 2008: 7.0% 2009: 7.0% GDP per capita: 5.5%	GDP: 2008: 4.6% 2009: 3.7% GDP per capita: 3.2%	GDP 2008: 7.1% 2009: 7.9% 2010: 8.0%	GDP: 2008: 6.3% 2009: 6.3% 2010: 5.9%	GDP: 2008: –6.6% 2009: –6.8% 2010: n/a

are well over the national average of 65 percent. In Namibia, the Caprivi region's population of around 80,000 make up 4.4 percent of the total (Afridev Associates 2004).

In the Middle ZRB, the rural-urban distribution varies greatly across provinces. In Zambia, 92 percent of the Eastern province live in rural areas; meanwhile, the rural population constitute 78 percent of the Southern and Central provinces, and only 21 percent of the Copperbelt Province (due to copper mining). Zambia's rural population (7.6 million, or 59 percent of the total) live primarily in small-scale farming households. Roughly 2.5 percent live in medium-scale farm households, 0.1 percent in large-scale farm households, and three percent in nonagricultural rural families (Zambia Central Statistical Office 2006). The biggest share live in the upper Kafue subbasin. The middle Kafue subbasin (mostly in Central Province) has a comparatively low population density, with only high concentrations in the Lukanga Swamps and upper Luangwa River (Scott Wilson Piésold 2003a). In Zimbabwe, the rural population constitute 64 percent of the total 13 million (2005).

The Lower ZRB has experienced rapid population growth. Malawi's population of 12.2 million has grown by two percent per year. Eighty-eight percent are rural dwellers, population density is very high (on average 105 persons per km^2), and population pressure is especially prominent in the southern region. Most Malawians are very young—46.2 percent are under the age of 15, which makes sustaining livelihoods difficult (Malawi National Statistical Office 2005). In Mozambique, the area within the Basin is estimated at 225,000 km^2 and is home to 3.8 million people (Beilfuss and Santos 2001). The area is sparsely populated, especially in the northeast part within the Tete Province, and with somewhat higher density along and around the Delta lying within the Zambezia and Sofala provinces. Similar to Malawi, the Zimbabwe part of the Lower Basin has higher population density and higher pressure on its resources.

2.6.3 Income and poverty

In the Upper ZRB, poverty is widespread. In 2006, 77 percent of those living in Zambia's Western Province and 72 percent in the Northwestern Province earned less than 300,000 kwachas (below the level of covering basic needs) (Zambia Central Statistical Office 2006). In Namibia's Caprivi region, poverty levels are significantly higher than the national average of 27 percent, and average household income is the third-lowest in the country (Afridev Associates 2004). Poverty is particularly high among female-headed households and among Silozi speakers. Poverty rates have fallen rapidly in Botswana since the early 1990s. Socioeconomic data from Angola is inadequate, but an estimated 70 percent of the population live below the poverty line (World Bank 2005).

In the Middle ZRB, poverty is significantly higher in rural areas, and there is considerable variation among the poor. In Zambia, 80 percent of the rural population have consistently lived in poverty over the past 10 years, while the urban proportion has decreased to 34 percent (Zambia Central Statistical Office 2006). Forty-two percent of the Copperbelt Province's population is registered as poor, while in the Central, Southern, and Eastern provinces, 72 percent, 73 percent, and 79 percent live in poverty, respectively. Food security assessments from 2001 indicate that food insecurity is higher in most of the rural districts of the Middle ZRB compared with the national Zambian average (Scott Wilson Piésold 2003a). In 2006 the income of 50 percent of Zambia's population was below the level of covering basic needs. This figure was 31 percent, 44 percent, 51 percent, and 66 percent for the Copperbelt, Central, Southern and Eastern provinces, respectively. This illustrates the relatively high level of average income in the regions along the line of railways and roads. In Zimbabwe poverty levels have increased dramatically over the past decades. In 2003 poor households made up 63 percent of the population, compared with 42 percent in 1995. Poverty has increased primarily in urban areas. Matabeleland North in the Basin has the highest poverty rate in the country, at 70 percent (World Bank 2007b:7).

The Lower ZRB is also characterized by high rural poverty. In Malawi the poverty line in 2004 was MK 16,165 per capita per year, which covers the cost of satisfying basic food and nonfood requirements (table 2.11.). Satisfying only basic food requirements was estimated to be MK 10,029. Fifty-two percent of Malawians fell below this sec-

Table 2.11. Mean annual household expenditure by region in Malawi (2005)

	Mean per capita expenditure MK	Expenditure on food %	Expenditure on housing, utilities, and furnishing %	Expenditure on other items %
Northern Region	22,340.30	61.4	19.8	18.8
Central Region	29,739.30	53.8	24.5	21.7
Southern Region	23,696.10	56.4	25.4	18.2
Malawi	26,058.60	55.6	24.4	20.0

Source: Malawi, National Statistical Office 2005.

ond level of income. As many as 64.4 percent of the rural population in the southern region were poor (comprising 50 percent of the national total), compared with roughly 30 percent in the urban areas. Gender disparities were also apparent; 59 percent of female-headed households were poor, compared with 51 percent of male-headed households. Across urban households, the difference was greater: 32 percent of female-headed compared with 24 percent of male-headed households. Food requirements made up more than half of household expenditure in all regions of Malawi. For the poorest quintile of the households, food requirements made up 61.1 percent of expenditure, while this figure was only 48 percent for the richest quintile.

Because staple crop requirements can only be covered for around four months of the year, food insecurity in Malawi is pervasive. Recurrent droughts, increasing fertilizer prices, and degradation of agricultural land are among the root causes (Gibbs 2003). Mozambique experienced a national decline in poverty from 69 to 54.1 percent between 1996 and 2003 (table 2.12.). Rural poverty rates also decreased from 71 to 55 percent. Populous provinces, such as Zambezia and Sofala, have also experienced significant reductions. The incidence of poverty is significantly higher among female-headed households (63 percent) than among male-headed households (52 percent) (Republic of Mozambique 2006b:23). Crop production is still by far the most important source of income, especially for poorer households. At the same time, the importance of wage labor, livestock production, and non-farm enterprise income is increasing, especially among richer rural households (World Bank 2006b: 41; 65–66). In Harare and Mashonaland Central, in the Lower ZRB in Zimbabwe, the poverty rates of approximately 50 percent are among the lowest in the nation.

Table 2.12. Poverty in select provinces and in rural/urban areas of Mozambique (1996–97 and 2002–03)

	Poverty headcount estimate	
Location	**1996–97**	**2002–03**
Zambezia	68.1	44.6
Tete	82.3	59.8
Sofala	87.9	36.1
Urban	62.0	51.5
Rural	71.3	55.3
Total country	**69.4**	**54.1**

Source: Republic of Mozambique 2006a:12.

2.6.4 Livelihood

Throughout the Basin, small-scale subsistence agriculture dominates employment. Livestock rearing and fisheries, especially in the floodplains and dambos, are also prominent. The economic value of the various natural resources and environmental services provided by land and rivers, either for consumption or sale, are rarely calculated. Available data indicate that their real (subsistence) economic value provides a considerable part of the overall rural household economy. The importance of forest, woodland, and wetland products for household nutrition and additional income should not be ignored. Those products are easily accessed by women and children, and improve their individual and household nutritional status and relative poverty rates. Across the Basin, livestock represent social status and insurance for most households. Furthermore, animals used for draught power are vital for tillage and small-scale farming practices.

In the high altitudes of the Upper ZRB, where rainfall is high and soil fertility poor, traditional, shifting, slash-and-burn subsistence agriculture is now giving way to a more settled state as population pressure increases. In the Angolan highlands and parts of the Northwestern Province of Zambia,[8] the areas of land not covered by Kalahari sands are among the most productive areas in the Basin. Farm sizes are larger than average, often exceeding 10 hectares. Rivers and streams also tend to be perennial, and irrigation is quite feasible. On the floodplains and dambos, agriculture is settled and very intensively practiced along the narrow, fertile margins between floodplains and wooded interfluves of Kalahari sands. Farm sizes range from two to four hectares. Apart from staple food crops, many other food products—such as vegetables, bananas, and mangoes—are grown for household consumption and local sale. Cash cropping has generally been limited to tobacco, cotton, and sugar production. Throughout the Zambian part of the Basin —particularly in and around the floodplains—cattle rearing is an important cash-generating activity. In Zambia's Western Province, livestock is owned by roughly a quarter of households, which is just under the national average. Cattle are particularly popular in the Western Province. Livestock ownership is generally lowest in the Northwestern Province. Cattle migrations from winter-grazing grounds on the floodplain to summer grounds on the higher surrounding sandplains occur annually. South and east of the floodplains are challenging areas for cattle, squeezed between the rising water of the floodplains and tsetse-infested woodlands of the Kalahari sands.

Fishing is another important livelihood in the Western Province, especially in the Barotse Floodplain. Over half of the population is involved in fishing activities, a vital contributor to household food consumption. Most of the population in the Barotse Floodplain depend on a mixed livelihood strategy, combining crop farming, livestock, fishing, and natural resource exploitation. This approach relies on the wetlands to provide protection from external shocks. Income and subsistence sources vary throughout the year because of seasonal changes. At the household level, the wetlands generate an annual net financial return of $405 on average. Of this, 83 percent is for home consumption. By far the most valuable assets are fish (43 percent of total and 73 percent of household cash income), floodplain grazing (29 percent of total), and crop production (22 percent of total) (Emerton 2003). Reeds, papyrus, and grasses contribute significantly to household income, although not as much as fish. Subsistence farming of maize, sorghum, millet, groundnuts, beans, and sweet potatoes constitute 60 percent of household incomes in areas such as the Caprivi region. Here, as in other areas with wetlands, most households sow crops in elevated ground during the rainy season and along riverbanks and in depressions during the dry season. This flexibility is crucial for food security.

With the exception of the Eastern Province, the Zambian part of the Middle ZRB has been dominated by the railways and proximity to urban areas in both Lusaka and the Copperbelt Province. Strong rural-urban links to urban centers provide employment opportunities and markets for agricultural products. Urban migratory patterns follow the growth and decline of mining and related industries. This part of the Basin also contains some of the largest and potentially most productive commercial farmlands in Zambia. In the northern part, the traditional, shifting slash-and-burn agricultural system is still practiced, though it is gradually being replaced by more sedentary systems. This area includes the Kafue River catchment, which is why large areas have been classified as forest reserves. Nearer to the urban centers of the Copperbelt, traditional production systems have largely given way to highly productive commercial farms and farming enterprises. Many areas, including forest

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[8] Solwezi, Kabompo, Mufumbwe, Kasempa, and Kaoma Districts.

reserves, are under increased agricultural pressure from cultivation, charcoal production, and returning migrants from urban or mining areas. The Central Province is characterized by large, relatively productive agricultural areas, some of which are dominated by small-scale production. Others are designated for large-scale commercial farms. Small-scale producers combine subsistence production of maize and traditional food crops with production of cash crops such as maize, cotton, and, recently, baby corn and paprika.

Considerable numbers of Zimbabwean small-scale farmers in the Federal era, along with Tonga herder-farmers (who could no longer sustain their livelihood in the dry Southern Province of Zambia primarily due to droughts and animal diseases), have migrated to the area since the 1970s. As population density slowly increases in this region, so does pressure on land and different forms of production and livelihoods become more difficult to reconcile (Denconsult 1998d, appendix II.1). Small-scale agricultural production in Zambia has changed radically since colonial times. During the mining and industrial development era, small-scale producers were encouraged to produce maize for sale to supply the urbanized workforce with staple food. Subsidized input packages, extension services, and equipment were provided by government parastatals, and prices were regulated centrally. Many elements of traditional production systems changed during this time, and both urban and rural populations adopted maize as their main staple crop. Land and soil were intensively exploited, especially in areas closer to urban centers and along railways. Other than the use of chemical fertilizers, little was done to maintain soil fertility. Now that subsidies have disappeared, prices are no longer guaranteed on inputs or crops, soils have been largely depleted, and most small-scale farmers are forced to revert to low-input production systems. Many are more inclined to adopt conservation farming techniques and other contemporary versions of sustainable farming systems (especially in the mid-Kafue and Central provinces), or to revert completely to the traditional shifting cultivation systems of slash and burn (as in the Upper Kafue and Northwestern provinces). Production of traditional crops such as beans and sweet potatoes has increased, and markets for such crops are also developing.

The Kafue National Park and adjacent game management areas cover the entire western part of Central Province and thus indirectly pressure the nonreserved parts of the province. On the other hand, the park and game management areas provide opportunities for tourism, which has not yet reached its full potential. In particular, involvement of the local communities in wildlife management has not yet been sufficiently developed. In spite of the establishment of community resource boards, local communities have experienced minimal gains from their involvement (Pavy 2006). Before construction of the ITT in the 1970s, the Kafue Flats were mostly inhabited by small fishing communities living along the river and Ila people, who let their herds graze the naturally flooded grasslands during the recession seasons. Since then, large parts of the Kafue Flats have been developed into commercial farm areas with potential for large-scale irrigated production. The area is not yet used to its full potential, but the herding communities have experienced increased difficulty in accessing previously occupied grasslands. Fishing was traditionally practiced in the Kafue Flats by the Twa people and the flats provided both fishing and cattle herding communities with protein (cattle owners rarely consume their livestock). Fishing potential has increased with construction of the reservoir.

Increased pressure on fishing elsewhere has led to an influx of fishermen into the Kafue Flats. The introduction of unsustainable fishing methods has put pressure on the fish stock.[9] The Southern Province has relatively low rainfall, fragile soils, and high population density. Erosion is therefore a serious problem in parts of the province. The traditional farming systems in the same area (including those of the Tonga) are characterized by a combination of farming and livestock herding. Increased population pressures have rendered this difficult to sustain, causing migration of herding families toward the Central Province. Livestock is still important in the

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[9] Rennie (1978), quoted in Scott Wilson Piésold 2003a, Chapter 2.

Southern Province, where 39 percent of households own livestock, compared with 27.2 percent in the Central Region (the average of Zambia as a whole) and only 11.6 percent in the Copperbelt Region. Some commercial farms and estates in the region grow tobacco, sugar, wheat, and coffee, but many of these farms are relatively unproductive. The Eastern Province adjacent to the Malawian border is also highly productive, with considerable small-scale farming; widespread use of animal-driven power; maize production for home consumption; and cotton, groundnuts and tobacco production for cash crops (Denconsult 1998d, appendix II.1).

The importance of maize for agricultural households might be an indicator of the relative dependence of many agricultural households on their own production to maintain household food security. In Zambia, 91 percent of agricultural households grow maize. For the regions of the Middle ZRB (except for Lusaka), that percentage is near 100, since many families produce both local varieties and hybrid maize (Zambia Central Statistical Office 2006). The Eastern Province also has the largest concentration of pigs, with 43 percent of the national total (Zambia Central Statistical Office 2006). In Zimbabwe the plateau in the southern part of the Middle ZRB is productive, hosting a large group of commercial farmers, while the northern and western parts of the Basin are dominated by communal lands with high population densities and large numbers of cattle (Denconsult 1998d). Farm types range from small-scale commercial resettlement farms to communal farms (Denconsult 1998d, appendix II.1). Large areas are still assumed to host small-scale farmers. Over 1.2 million smallholder farming families in Zimbabwe—70 percent of the population—hold an average of three hectares each, although the land is comparatively marginal for agriculture in low rainfall areas and with limited access to productive resources and infrastructure (FAO Investment Centre Division 2004). These farmers practice rain-fed agriculture using low-input, low-output technologies. Agricultural production in Zimbabwe has been constrained over the past decade, and maize production is reported to have declined by half between 1995 and 2003. Up to a third of the population has depended on food aid in recent years (World Bank 2007b). Furthermore, many households are increasingly dependent on remittances.

A Poverty Assessment Study Survey from 2006 shows that 35 percent of household income came from remittances.[10] Livestock is crucial for crop agriculture, as 95 percent of agriculture in communal areas depends on draught power for tillage. Livestock populations, including livestock for export, have recently been adversely affected by drought and outbreaks of communicable diseases like foot-and-mouth disease and by the decline in commercial livestock farming since the implementation of significant land reforms (FAO Investment Centre Division 2004).

In the Lower ZRB, a very large proportion of the population is involved in agriculture, especially in Malawi. According to the National Statistics Office of Malawi, 75.4 percent of all employed Malawians over 15 years old were farmers belonging to the Mlimi group (2004). In the northern region, 86 percent were Mlimi; in the central region, 83.6; and in the southern, 67.3 percent (Malawi National Statistical Office 2005). The Malawi Demographic and Health Survey (2004), which uses a slightly different definition of *farmer*, registered similarly high levels of engagement in agriculture. Figures show a very high participation of women in agricultural activities; men only dominate in the northern region. Agricultural production in Malawi is mainly carried out by small-scale farmers who combine subsistence agriculture with cash crop production. Because of Malawi's high population pressure, farms are very small; this is especially true in the southern region, where they can be as small as 0.2 hectares (Denconsult 1998d, Appendix II.1). In the northern and central regions, average farm sizes are between one and two hectares. According to CODA (2006), 25 percent of small-scale farmers cultivate less than 0.5 hectares, 30 percent cultivate between half to one hectare, 31 percent cultivate between one to two hectares, and 14 percent cultivate more than two hectares.

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[10] Poverty Assessment Study Survey II (PASS II), draft report, December 2006, here cited from World Bank 2007e, p. 7.

Small-scale farmers have customary user rights to their land. Until recently, however, these rights were not formally registered. The insecurity of landholding has had a negative impact on incentives to maintain soil fertility and improve land productivity with irrigation structures. A new national land policy approved in 2002 initiated registration and formalization of user rights and opened up for private leasehold estates (CODA 2006). Maize is the dominant staple food throughout Malawi, where more than 93 percent of agricultural households produce it (Malawi National Statistical Office 2005). In high rainfall areas, cassava can be the staple crop. In the dry south along the Shire Valley, sorghum partly replaces maize, and rice is important on the western lake shore plain in Tanzania. Among cash crops, tobacco (particularly burley tobacco) is economically the most important for small-scale farmers, followed by cotton and groundnuts (Denconsult 1998d, Appendix II.1). Most agricultural production in Malawi is rain-fed, but dry season cultivation in the wet depressions (Dimba) is also very common. As many as 36 percent of farming households cultivate Dimba crops. This average covers a huge variation between districts within each of the three regions. Some of the highest levels of Dimba cultivation are found in Nsanje in the southern region (59.6 percent), Mchinji in the central region (54.6 percent), and Mzimba in the northern region (53.8 percent). On average, only 27 percent of Dimba fields are irrigated, and most irrigation is restricted to traditional irrigation methods (such as watering cans and stream diversion).

For many farming families, livestock constitute a safety net during droughts and lean periods (CODA 2006). But livestock numbers have declined over the past decades due to droughts, diseases, and other shocks. At present, most families only own small livestock, the most common species being chicken (owned by 88.7 percent of all agricultural households), followed by goats (34.9 percent) and pigs (10.5 percent). Only eight percent of agricultural households own cattle. The highest proportion of agricultural households owning cattle is found in the northern region (18.9 percent) while goats are particularly common in the central and southern regions, where they compose 39.9 and 35.2 percent of total livestock, respectively (Malawi National Statistical Office 2005). Integration of livestock production and crop production (such as use of crop residues for feed and use of manure for fertilization of fields) seems to be poorly developed, especially in the southern part of the country. In addition, in most of the country, animal traction and other forms of mechanization of crop production are applied to a very limited extent by small-scale farmers. Commercial private farms and corporate estates are few and small in size, and they tend to be crop specific, growing tobacco, rubber, tea, coffee, or other cash crops. These farms, which occupy approximately 13 percent of agricultural land in Malawi, provide employment for a number of rural people, but large-scale farming plays a lesser role in Malawi than in Zambia (CODA 2006: 7).

Fishing sustains the livelihood of small fishing communities along Lake Malawi/Niassa/Nyasa, along the Shire River, and in the floodplains and swamps of the wetlands in the south of the country. Fishing in the floodplains and swamps is mainly done from dugout canoes using traditional techniques. Even though considerable areas have been classified as National Parks and Wildlife Reserves, wildlife numbers are very low, and thus play a relatively small role in rural livelihoods in Malawi. Furthermore, the management arrangements in and around the National Parks and Wildlife Reserves have not involved the local communities to any significant extent. The incentive for local communities to contribute to sustainable wildlife management is very slim (CODA 2006: 60ff). As with other rural communities in the ZRB, collection of natural resources on communal (forest and woodland) areas constitute an important part of the subsistence economy for many households.

The most important natural resource collected in Malawi is firewood. Because of population pressure, deforestation constitutes one of the main environmental threats in Malawi. Of Mozambique’s 20.5 million population (2007), the number who are economically active averaged nine million in 2003. As many as 79.6 percent of adults are engaged in agriculture, compared with 12.7 percent in commerce and services. Women are particularly prevalent in the agricultural sector, making up almost two-thirds of the farming workforce. On the other hand, men dominate all other sectors even though women occupy more than one-third of all jobs in commerce and services. Many new jobs have been created in urban areas, especially in the service sector, and men predominantly have entered these new jobs.

The area north of Lake Cahora Bassa has very low agricultural productivity and low population density. The farming system here is dominated by rain-fed subsistence agriculture and cash crop production by small-scale farmers. In the easternmost part of Tete (bordering Malawi), rain-fed cash crop production is increasingly important and where international companies have begun to establish outgrower schemes with paprika and other export crops. The subbasin falling within Sofala and Zambezia is dominated by wetlands and includes the Ramsar site of the Marromeu Complex on the southern bank of the Zambezi River.

Traditional livelihood systems were adapted to the seasonal flooding of large areas. A combination of rain-fed and recession agriculture has been practiced by the people living along the river and in the wetlands, where poor yields in one area are often counterbalanced by higher yields in other areas in the same season (Beilfuss and Brown 2006). Farming households cultivate an average of 1.5 hectares of rain-fed area for food crops—including maize, sorghum, millet, cassava, groundnuts, beans, cowpea, and sweet potatoes—mainly for consumption and to a lesser extent, cash crops such as cotton, tobacco, sugarcane, and sunflower. Mechanization with animal traction or similar is almost nonexistent. The fields of naturally flooded rice farms have an average size of 0.8 hectares. Irrigation techniques are traditional and use low-level technology (Beilfuss and Brown 2006). Furthermore, many families have combined the cultivation of crops with some livestock rearing, freshwater or estuarine fishery, and the collection of natural resources such as fuel wood, palms, papyrus, reeds, grass, wild fruits, honey, and medicinal plants. At $96 per household per year, fish and crustaceans constitute by far the biggest contributor to household income in the Delta, as in the other three major wetland areas of the Basin. According to this study, palm (with a contribution of $11 per year) is the second-largest natural resource contributor to household economy in the delta (Turpie and others 1999:161, table 4.6.26)

In the dry season, cattle graze on grassy plains. Poor surface drainage prevents tree growth as well as cropping. The Zambezi Delta is reported to have supported more than 50,000 cattle in the 1970s, the majority of which were associated with the Sena Sugar Estates at Marromeu, but cattle was also herded in districts such as Chinde, Mopeia, and Caia. Livestock were decimated during the prolonged civil war, and the area is now reported to hold less than 5,000 heads, although restocking programs have been introduced (Beilfuss and Brown 2006). These are two large sugar estates near the river, where pockets of soil with natural surface draining channels can be found, and these are important for agricultural output and employment. Other irrigated commercial crops such as vegetables, fruit trees, rice, tobacco, and cotton are grown on smaller commercial farms. The agricultural sector in Mozambique has experienced positive developments in recent years, which in turn has contributed considerably to the overall decrease in rural poverty. There has been a diversification of both food crop and cash crop production, more small-scale farmers have been involved in contract farming, and large-scale farms have created jobs for rural households. Much of the increased production stems from extension rather than intensification of production. The need to improve productivity per hectare through better land management and mechanization is widely recognized. The largest increases in production were found in the central regions of the country, including in the Lower ZRB, with a particularly high increase in the Tete Province (World Bank 2006b).

Socioeconomic infrastructure development in the provinces of Zambezia, Tete, and Sofala was very positive between 1996–97 and 2002–03. Roads, markets, public transport, communication, modern lighting, potable water, and sanitation improved significantly (Republic of Mozambique 2006b:16). The northern parts of Zimbabwe fall within the Lower ZRB and have relatively high temperatures and low or erratic rainfall. The area has primarily been laid out for communal farming, with a high density of both population and cattle. Maize is the main staple crop, in some areas supplanted by sorghum and millet, and cotton is the main cash crop (Denconsult 1998d, appendix II.1). On the plateau farther south, commercially irrigated farms with small or large dams dominate, while the Eastern Highlands are well suited for commercial fruit, vegetable, coffee, and tea production.

2.6.5 Gender and youth

Across the Basin, women dominate the agricultural workforce. Often, they are responsible for the collection and processing of natural resources and in most cases, their roles are linked to subsistence production to ensure household food security. Women's participation in cash production is less pronounced, and their control over cash income from agriculture is limited. The large number of female-headed households is in part explained by the migration of men. In contrast, the mining districts along the Upper Kafue have more males than females, reflecting job opportunities in these districts (Scott Wilson Piésold 2003a). The decline of the mining industry has nevertheless resulted in increased participation of women and children in the informal service sectors in the urban areas of the Copperbelt and increased out-migration from urban areas toward rural areas. In rural areas, women are used as paid farm labor, and they also carry out work on the household subsistence farm. Poverty is significantly higher among female-headed households, which reflects their marginal position in both rural and urban areas (Zambia Central Statistical Office 2006).

The number of jobs in the formal sectors along railway areas and in the mining industry has fallen. Young people—especially young men—therefore struggle to find jobs with sufficient income to sustain a family. This in turn puts increased pressure on households to create jobs and income through agricultural activities. In Malawi, women participate more than men in almost all farming and livestock rearing activities—from land preparation to harvesting—in the small-scale farming systems. With very little control over and access to resources, and with little decision-making power, women get little exposure to agricultural advice and technological improvements. This is probably partly due to the relatively low level of mechanization and the considerable migration of men in search of off-farm employment. In Malawi, women account for 70 percent of the total farm labor (CODA 2006: 85ff). In addition to farm labor obligations, women are responsible for fetching fuel wood and water; processing food and cooking; caring for children, the elderly, and the sick; and general housekeeping. In addition, many women are involved in trade, beer brewing, or other income-generating activities despite a very low profit margin (CODA 2006: 88ff).

According to tradition, in most Malawian rural communities, men control the family land and make the ultimate decisions on crops to be grown. Women's decision-making influence is greater for, yet limited to, the smaller vegetable gardens allotted to them. Furthermore, men are responsible for marketing cash crops; women only food crops. Thus, 68 percent of income derived from agriculture is controlled by men (CODA 2006: 85). Therefore, despite the dominance of women in farm labor, they rarely consult extension services; leaving this exchange to their male household members (this is even the case in female-headed households, where no male household members are present to participate in extension activities). Similarly, access to credit and farm inputs is much lower for female-headed households and for women in general. Twenty-three percent of all households in Malawi are registered as female headed (Malawi National Statistical Office 2005). An even larger proportion of households are de facto female headed because of male migration or divorce. Similar to Malawi, more women than men in Mozambique live in rural areas, and women make up the majority of the agricultural labor force. With more men taking up employment in other sectors, this cycle is being reinforced; women stay in the lower levels of agricultural production and do not benefit from diversification of agricultural production and increase in cash crop production. Women still have the primary responsibility to do household chores and produce food, but they have very limited access to technology, fertilizer, and credit. Women are therefore highly restricted in their ability to engage in agricultural diversification or other income-generating activities (Republic of Mozambique 2006b).

2.6.6 Health and education

Life expectancy at birth is low throughout the ZRB: 56 years in Botswana and Tanzania, 47 in Namibia and Mozambique, 42 in Zambia and Angola, 40 in Malawi, and 33 years in Zimbabwe. Health challenges, such as the prevalence of malaria, respiratory infections, eye infections, skin infections, and diarrhea demonstrates the deleterious effects of living close to still water; poor access to clean drinking water and sanitation facilities; and proximity to urban, industrial pollution, all of which characterize large parts of the Basin.

Malaria and other diseases related to proximity to still water are highly prevalent in the Upper Zambezi River Basin. Malnutrition among children under the age of five seems to be relatively low in the Western Province of Zambia compared with the rest of Zambia, with levels of stunting (39.6 percent, low height for age, a sign of chronic malnutrition), underweight (4.5 percent), and wasting (17.0 percent, lower than average weight for height, a sign of acute malnutrition) all under the national average. The Northwestern Province shows a significantly higher than average level of wasting (23.1 percent) and more than twice the level of underweight children (13.2 percent), while stunting (49.1 percent) is below the national average (Zambia Central Statistical Office 2006). Levels of malnutrition among children under the age of five in the Caprivi Region in Namibia are similar to the national levels, with 25 percent showing signs of moderate long-term malnutrition. The region is subject to alarmingly high rates of HIV/AIDS infections, with a prevalence rate of 33 percent in 2000, higher than in any other part of Namibia (Afridev Associates 2004). The prevalence rate is 17 percent in Botswana (IMF 2007b), and four percent in Angola (World Bank 2006a), and 16 percent in Zambia.

In the Middle Zambezi River Basin, the general health status has deteriorated considerably in Zambia due to economic recession and the HIV/AIDS pandemic. Prevalence rates among those aged 15–49 were significantly higher in urban areas than in rural areas in 1999. Rates were between 26 and 28 percent in the urban districts of the Copperbelt, less than 20 percent in the urbanized districts in the southern region, and only 11 to 14 percent in rural districts. Rates are decreasing in the urban districts but still increasing in rural districts.[11] Child health indicators for the Copperbelt, Central, and Southern provinces are relatively close to the Zambian averages of 54.2 percent for stunting, 5.9 percent for underweight, and 19.7 percent for wasting. Only the central region exceeds the average rates of stunting and underweight, while the southern region is slightly over the average for underweight and wasting.

In Zimbabwe life expectancy has fallen sharply since the early 1990s. The prevalence of HIV/AIDS reached a peak of 25 percent in the early 2000s and declined to 18.1 percent in 2005–06, but remains among the highest in the world (World Bank 2007b). The proportion of underweight children under five was 13 percent in 1999, with significantly higher levels in north Matabeleland (18.9 percent) and in west Mashonaland (16.7 percent) (United Nations Development Program [UNDP] 2003).

In the Lower Zambezi River Basin, malaria, diarrhea, and to a lesser extent cholera are prevalent. Malnutrition is pervasive in all regions and income groups in Malawi. This can partly be explained by the high reliance on maize—maize comprises 93 percent of cereal consumption (Zambia Central Statistical Office 2006). The levels of under-five children suffering from stunting, underweight, and wasting are high (table 2.13.).

In Malawi HIV/AIDS prevalence was 14.4 percent in 2003, which is lower than the average for southern Africa. Furthermore, the rate appears to be steady, indicating a curved spread. Urban areas were hardest hit, at 23 percent compared with 12.4

Table 2.13. Prevalence in Malawi of stunting, underweight, and wasting among children aged six to 59 months (2005)

	Stunted	Underweight	Wasted
Northern Region	38.1	19.8	5.6
Central Region	47.8	24.3	4.0
Southern Region	39.7	20.4	5.1
Malawi	43.2	22.2	4.6

Source: Malawi National Statistical Office 2005.

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[11] Zambia Ministry of Health (1999), here taken from Scott Wilson-Piésold 2003a, Chapter 2 (2–16).

percent in rural areas. The southern region, with a prevalence of 19.5 percent, is more stricken than any of the other regions in the country.

In Mozambique, the level of child malnutrition has been slowly decreasing since 1996–97. In 2003, 30 percent of children under five were stunted, 22.3 percent were underweight, and four percent suffered from wasting. HIV/AIDS prevalence in the Mozambican part of ZRB is among the highest in the country. In 2004 estimates of prevalence rates were over 26 percent among adults (15–49 years) in Sofala, over 18 percent in Zambezia, and over 16 percent in Tete (Republic of Mozambique 2005: 41), compared with the rising country average of 16 percent.

The proportion of underweight under-five children is high in the Zimbabwean parts of the Lower ZRB. The prevalence of underweight children ranged from 15.2 percent (Mashonaland East) to 17.4 percent (Mashonaland Central). By comparison, the national average was 13 percent in 1999 (UNDP 2003).

In the Upper Zambezi River Basin, the educational levels vary between riparian countries. Primary school enrollment has reached almost 100 percent in the Caprivi Region, as in the rest of Namibia (Afridev Associates 2004); meanwhile, it is 95 percent in Botswana (IMF 2007b), 66 percent in Zambia (Scott Wilson Piésold 2003a), and a low 56 percent in Angola (World Bank 2006a). Adult literacy in Namibia is 83 percent for women and 87 percent for men (World Bank 2007a), while only 67 percent overall in Angola (World Bank 2006a).

As with health in the Middle Zambezi River Basin, educational attainment has suffered seriously from the general economic decline in Zambia since the 1980s. The rising number of students has been serviced through more intensive use of existing infrastructure with larger classes, shift teaching, and shorter days. Net enrollment in primary school fell from 80 percent to 66 percent between 1996 and 2000. Developments in enrollment since 2000 have not yet been documented. More recent numbers indicate a resurgence to 96 percent.

Adult literacy in Zimbabwe is relatively high compared with neighboring countries, with an average literacy rate of 88.1 percent in 2001 and with only minor variations among regions (north Matabeleland has the second-lowest level at 83.2 percent) (UNDP 2003). Net enrollment rates in primary school have remained high in Zimbabwe at around 96 percent, with almost equal enrollment of girls and boys, although completion rates seem to be declining.

In the Lower Zambezi River Basin, the general educational level is poor. In Malawi, 28 percent have no education, 56 percent have attended primary school, and 18 percent have attended secondary education or above (Malawi National Statistical Office 2005). Among rural women in Malawi, 33.4 percent have no education, while 61.3 percent have attended primary school, and five percent have attended secondary school or higher. For rural men, the figures are 22.9 percent with no education, 66.4 percent with a primary school education, and 10.4 percent with secondary or higher education (Zambia Central Statistical Office 2006). Only 52 percent of adult women are literate, compared with 76 percent of adult men.

The overall adult literacy rate in Mozambique was 46.4 percent in 2003. Rates differed significantly between men (63.3 percent) and women (32 percent) (Republic of Mozambique 2005: 13). In the agricultural sector, almost 87 percent of the labor force has no formal education (beyond basic literacy) though that figure has increased slightly since 1997. School enrollment has improved since 1997. In 2002 enrollment rates for girls reached almost the same level as for boys (World Bank 2008b, annex table 2). The net enrollment rate of girls in primary school was 73.2 percent in 2004.

Adult literacy in Zimbabwe is high compared with neighboring countries. Literacy levels in Mashonaland East and West are almost as high as the national average. In 2001 Mashonaland Central had the lowest rate in the country, at 80.2 percent (UNDP 2003).

3

Beneficial Uses of Water

3.1 ENERGY AND HYDROPOWER

Hydropower is one of the major resources in the ZRB. Total developed capacity is approximately 5,000 MW, primarily on the Zambezi River's main stem and along two of its major tributaries, the Kafue and the Shire Rivers. The total potential development is some 13,000 MW. Yet, because of regional power exchanges and the desire to integrate the power pool across countries, development of energy within the Basin cannot be considered in isolation. The main institution that oversees the power sector in southern Africa is the Southern African Power Pool (SAPP).

3.1.1 Southern African Power Pool (SAPP)

The SAPP was created in August 1995 when member governments of the Southern African Development Community (SADC) (except for Mauritius) signed an intergovernmental memorandum of understanding (MoU) for the formation of an electricity power pool in the region under the name of the SAPP. The objective of the SAPP is to provide reliable and economical electricity supply to consumers through coordination of and cooperation in the planning and operation of the various systems to minimize costs and maintain reliability. Development of a pool plan for optimal expansion of the generation and transmission systems for the region supports this objective. The potential benefits of coordinated planning include reduced required generating capacity, reduced fuel costs, and improved use of hydroelectric energy.

The objectives of the SAPP are to:

- Provide a forum for the development of a world-class, robust, safe, efficient, reliable, and stable interconnected electrical system in the southern African region;
- Coordinate and enforce common regional standards of quality of supply, measurement, and monitoring of system performance;
- Harmonize relationships among member utilities;
- Facilitate the development of regional expertise through training programs and research;

- Increase power accessibility in rural communities; and,
- Implement strategies in support of sustainable development priorities.

All participating electricity enterprises must be situated in a country that was a member of the SADC in September 1994. Full membership is restricted to one national utility per country. Membership of non-SADC country utilities is subject to approval by a two-third majority of the SAPP Executive Committee and subsequent ratification by the SADC Energy Ministers' Committee. The SAPP members have signed the Inter-utility MoU and can only participate in the Planning and Environmental Subcommittee. A key objective of the Planning Subcommittee is to conduct relevant studies to allow for the construction of interconnections with members who are still isolated from the main network. There are two categories of membership:

- Operating members are signatories of all principal documents governing SAPP. Their system is interconnected with at least one other member. They are responsible for meeting all policy procedures and guidelines established by the SAPP.
- Non-operating members are signatories to only one SAPP principle document—the Inter-utility MoU. They participate in all activities except those related to operation of the power pool.

National utilities that are members of the SAPP include:

- Electricidade de Moçambique (EdM)
- Botswana Power Corporation (BPC)
- Electricity Supply Corporation of Malawi (ESCOM)
- Empresa Nacional de Electricidad (ENE, Angola)
- ESKOM, Republic of South Africa
- Lesotho Electricity Corporation (LEC)
- NamPower, Namibia
- Société Nationale d'Électricité (SNEL), Democratic Republic of Congo
- Swaziland Electricity Board (SEB)
- Tanzania Electric Supply Company (TANESCO)
- Zambia Electricity Supply Corporation (ZESCO)
- Zimbabwe Electricity Supply Authority (ZESA)

In addition, two private utilities are also members of the SAPP. They are:

- Hidroeléctrica de Cahora Bassa (HCB), owned by the majority shareholder (government of Mozambique) that operates the Cahora Bassa hydropower plant.
- MONTRACO, a joint venture between ESKOM and EdM that owns and operates the Mozambique to South Africa transmission line.

The SAPP power system consists of nine interconnected utilities, as well as three isolated utilities: ENE, ESCOM, and TANESCO. ESCOM and TANESCO plan to interconnect by 2010. Another interconnector between the HCB and ESCOM system is nearly complete. Many important factors have helped shape the SAPP region's current power system: large, low-cost coal deposits (especially in South Africa leading to the predominance of coal for fuel and electric energy production in the region); substantial hydroelectric potential throughout much of the region (especially along the Congo, Zambezi, and Kafue rivers, see table 3.1); the dominance of South Africa which supplies about 80 percent of demand and generation for electricity; the necessity of long-distance, high-voltage transmission facilities to move large amounts of power from coal fields and hydro sites; and the region's very large surface area, with nearly 3,000 kilometers between Luanda and Dar es Salaam and nearly 3,500 kilometers between Kinshasa and Durban.

Nine of the national systems are interconnected:

- A +500 kV DC link connects Inga in the western Democratic Republic of Congo (DRC) and Kolwezi in the southeastern DRC, ultimately connecting to the ZESCO at 220 kV.
- A +533 kV DC link connects Songo near HCB in Mozambique with ESKOM's Apollo substation in South Africa.
- The 765 kV ESKOM system extends from the coalfields in northeastern South Africa toward Cape Town in the southwest.

Table 3.1. SAPP regional network generation capacity (2007)

	Installed capacity (MW)				
Utility	**Coal**	**Hydro-power**	**Natural gas**	**Others**	**Total**
BPC	120	0	0	0	**120**
EdM	0	2,157	0	64	**2,221**
ENE	0	474	250	25	**749**
ESCOM	0	282	0	17	**299**
ESKOM	37,425	2,061	0	342	**39,828**
LEC	0	73	0	0	**73**
NamPower	108	240	0	24	**372**
SEB	0	42	0	0	**42**
SNEL	0	2,333	0	0	**2,333**
TANESCO	0	561	485	78	**1,124**
ZESCO	0	1,752	0	10	**1,762**
ZESA	1,155	750	0	0	1,905
Total	**38,808**	**10,725**	**735**	**560**	**50,828**
% Total	76%	21%	1%	1%	**100%**

Source: NEXANT 2007.

- ESKOM's 400 kV system connects through the BPC to ZESA, to NamPower and to EdM directly and via the SEB.
- ESKOM also connects to NamPower and EdM at 220 kV.
- ESKOM connects to the BPC, LEC, and EdM at 132 kV.
- The ZESCO's main system is at 330 kV, supplemented by a 220-kV system operated by the Copperbelt Energy Corporation PLC (CEC) in the north. Its connection with the ZESA at Kariba is at 330 kV.
- The ZESA operates both 330 kV and 400 kV systems. There is also a second 330 kV interconnection from Songo, near HCB.
- The ZESA and BPC are connected at 220 KV between Marvel and Francistown, but that line is normally open.
- The three isolated systems have lower voltage lines. The ENE has three separate isolated areas and a maximum voltage of 220 kV. The ESKOM expects a 220 kV interconnection with EdM in the near future, but until then its maximum voltage is 132 kV. The TANESCO expects a 330 kV interconnection with the ZESCO by 2010, but until then its maximum voltage is 220 kV.

The World Bank sector strategy and implication for regional approaches is outlined in Appendix IV of its Regional Integration Assistance Strategy (RIAS) (March 2008). A summary of the strategy is reproduced in table 3.2.

The power sector in southern Africa reflects the general situation in Sub-Saharan Africa, which is experiencing a power crisis characterized by insufficient capacity, low electricity connection rates, high prices, and poor reliability. The power sector in the region has the following features:

- A history of underinvestment followed by a recent abrupt change from power surplus to power deficit. Power shortfalls are now common and causing load shedding and economic disruption in a number of the SAPP countries, in particular Mozambique, Malawi, South Africa, Zambia, and Zimbabwe.
- The pool is dominated by ESKOM of South Africa, which accounts for about 80 percent of the total SAPP demand and produces roughly the same percentage of energy.
- Coal is the predominant source of generation (77 percent), sourced from the large deposits in South Africa and Botswana, but many of the coal-fired power stations are old and need refurbishment.
- The balance of the system is mainly hydropower. The Congo and Zambezi river basins have a number of large hydropower plants and the potential for more. There are also many smaller schemes throughout the region.
- Nuclear power accounts for only about five percent of generation (from the Koberg plant in South Africa), but it is growing and likely to become significantly more important in the future. South Africa's Nuclear Energy Corporation expects the nuclear share to increase to 30 percent by 2030.
- Transmission distances are large. Moving substantial amounts of power around, from distant coal fields or hydro sites, requires high-voltage

Table 3.2. World Bank Regional Integration Assistance Strategy: Africa Power Sector (2008)

World Bank Regional Integration Assistance Strategy	Objectives
Strategy: Clean Energy for Development Investment *Framework: World Bank Group Action Plan (2007)* • Supports Africa Energy Scale-up Program to increase number of households with access to modern energy from current low level of 25% to 35% by 2015 and 47% by 2030 • Supports transition to a low carbon economy • Supports countries' adaptation to climate variability and change • Explores options for enhanced financial products	
Strategy: Africa Region: Energy Challenges and Opportunities Energy Scale-up Plan for Africa (2007) • Growing consensus that action on energy is critical to reduce poverty • Regional programs including large hydropower generation, transmission, and hydrocarbon projects are vital for region countries • Regional institutions are gearing up to deliver **Action Plan for Energy Access in Sub-Saharan Africa** • Track 1: Rollout grid and off-grid programs • Track 2: Enhance generation and transmission (development of hydropower, gas, and other resources at national and regional level – main avenue of Bank support) • Track 3: Electricity/lighting for services and institutions • Track 4: Lighting bottom of pyramid • Track 5: Sustainable fuels	Support development of regional power generation and transmission projects, and national projects that have a regional impact. Support capacity development of regional economic communities (RECs), river basin organizations (RBOs), and regional power pools.

Source: World Bank Regional Integration Assistance Strategy (March 2008).

transmission facilities over long distances and often across international borders.

- Indigenous hydrocarbon resources are of growing importance. Offshore gas fields in Mozambique and Namibia offer the prospect of clean-burning thermal generation as an alternative to coal.

After a long period of low economic growth and power surpluses, the SAPP region is now experiencing serious power deficits, which has resulted serious economic repercussions in a number of countries, including South Africa, Malawi, Zambia, and Zimbabwe. There is now a serious drive to rehabilitate and upgrade existing hydro and thermal power stations and to build new generating capacity.

3.1.2 Existing hydropower plants in the Zambezi River Basin

A total of almost 5,000 MW of hydropower has been developed in the Basin. The major hydropwer plants (HPP) are listed in table 3.3.

Victoria Falls

Victoria Falls hydropower consists of three power plants:

- Plant A, commissioned in 1937, has an installed capacity of 8 MW (2 x 1 MW and 3 x 2 MW) but has had its rating lowered to 4.8 MW.
- Plant B, commissioned in 1968, has an installed capacity of 60 MW (6 x 10 MW).
- Plant C, commissioned in 1972, has an installed capacity of 40 MW (4 x 10 MW).

All three plants have a common nominal effective head of 105–106 meters and are fed by a left-bank diversion at the level of the falls. The plant does not run year round; production is curtailed during low flows to maintain discharge at the falls. The average power factor is 32 percent. Since the falls are among the world's most important natural monuments, there are no plans to upgrade existing units or add capacity.

Table 3.3. Existing hydropower in the Zambezi River Basin

Name	Utility	River	Country	Type	Capacity (MW)
Victoria Falls	ZESCO	Zambezi	Zambia	Run-of-River	108
Kariba	ZESCO/ZESA	Zambezi	Zambia & Zimbabwe	Reservoir	1,470
Itezhi Tezhi	ZESCO	Kafue	Zambia	Reservoir	n/a
Kafue Gorge Upper	ZESCO	Kafue	Zambia	Reservoir	990
Mulungushi	ZESCO	Mulungushi	Zambia	Reservoir	20
Lunsemfwa	ZESCO	Lunsemfwa	Zambia	Reservoir	18
Lusiwasi	Private	Lusiwasi	Zambia	Pondage	12
Cahora Bassa	HCB	Zambezi	Mozambique	Reservoir	2,075
Wovwe	ESCOM	Wovwe	Malawi	Pondage	4.35
Nkula Falls A&B	ESCOM	Shire	Malawi	Pondage	124
Tedzani	ESCOM	Shire	Malawi	Pondage	90
Kapichira stage I	ESCOM	Shire	Malawi	Pondage	64

Source: NEXANT 2008.

Kariba

The Kariba reservoir provides storage for two power plants: the Kariba South Bank powerplant, which has an installed capacity of 750 MW; and the Kariba North Bank power plant, which has an installed capacity of 720 MW. Kariba Dam was completed in 1958, and the power plants have been in operation since 1961. The Kariba reservoir is the second largest man-made lake in Africa after the Lake Volta, with a surface area of 5,577 km^2 and a volume of nearly 65 km^3 at a full supply level of 488.5 meters. The Kariba South Bank powerplant was recently upgraded to 750 MW and the Kariba North Bank to 720 MW. Each powerhouse consists of six identical units. At Kariba North, space was allocated at construction time for housing two future supplementary units.

The spillway consists of six gates located at the top of the dam. These gates cannot be operated to release artificial floods at lower reservoir levels. Since the spillway is inadequate to pass extreme floods, the reservoir is drawn down prior to the flood season.

Itezhi Tezhi and Kafue Gorge Upper

Itezhi Tezhi Dam (ITT) and reservoir was completed in 1977 to regulate the Kafue Gorge Upper power plant (KGU), which was completed in 1972. The power plant is being upgraded from 900 to 990 MW. Each of its six units have been refurbished, turbines reprofiled, and generators rewound and commissioned. At its full supply level of 1,030.5 meters, the Itezhi Tezhi reservoir has a surface area of 390 km^2 and a volume of over six km^3. The reservoir provides only partial regulation to the KGU: below the dam the lower Kafue River meanders for some 250 kilometers through the Kafue Flats, a vast expanse of wetland fed by flash tributaries. Outflow from Itezhi Tezhi therefore lags for about one and a half, to two months. Similar to Kariba, the Itezhi Tezhi spillway is inadequate to pass extreme floods, and a rule curve has been designed to draw the reservoir down prior to flood seasons. In addition, the reservoir must release a minimum flow of 40 m^3 per second: 25 m^3 per second for environmental concerns and 15 m^3 per second for water abstractions downstream of the flats to provide drinking water for Lusaka and Mazabuka as well as other usages. During the month of March the minimum release is increased to 315 m^3 per second.

Mulungushi

The Mulungushi power plant is located on the Mulungushi River in the Luangwa subcatchment.

It consists of four Pelton turbine units of various capacities, installed between 1924 and 1947 with an effective head of 325 meters and an original capacity of 20 MW, although that has been downsized to 16 MW. A small reservoir with 0.23 km^3 capacity, located five kilometers upstream of the powerhouse, provides regulation.

Lunsemfwa

The Lunsemfwa powerhouse is located on the Lunsemfwa River, a tributary of the Luangwa. Commissioned in 1945, its total capacity is 18 MW through three Francis units of six MW each. Flow regulation is provided by a reservoir located some 30 kilometers from the powerhouse, with a surface area of 45 km^2. Some miscellaneous information indicates that the Lusiwasi powerhouse, located on the Lusiwasi River within the Lungwa subcatchment, has been upgraded from 12 to 52 MW. This information could not be confirmed and recent energy-related studies do not mention the upgrade. According to 2007 parliamentary debates transcripts, the ZESCO was refurbishing Lusiwasi, which has a capacity of only four MW.

Cahora Bassa

The Cahora Bassa development is the largest hydropower development in the Basin. It consists of an arch dam, a large reservoir with a surface area of 2,675 km^2, a volume of 51.75 km^3 at a full supply level of 326 meters, and a powerhouse of five 415 MW Francis units (totaling 2,075 MW). The scheme was completed in 1974 with the primary objective to export power to South Africa. During the civil war, however, the interconnector was destroyed. For 20 years, it provided only 18 MW to the city of Tete and the town of Songo. Full production was reestablished in 2000. Unlike Kariba, the Cahora Bassa spillway is located below the minimum operating level and can therefore discharge to partially restore natural flooding at any reservoir level. The development lacks a bottom sluice to empty the reservoir, however, and the total spillway capacity is inadequate to handle extreme floods. Prior to the flooding season, the reservoir is therefore drawn down to preset levels prescribed by a rule curve.

Nkula Falls

The Nkula Falls hydropower development, commissioned in 1966 and located on the Shire downstream of Liwonde, consists of two powerhouses: Nkula A (three Francis turbines of eight MW, totaling 24 MW) and Nkula B (five Francis turbines of 20 MW, totaling 100 MW). The total capacity at Nkula Falls is 124 MW.

Tedzani

The Tedzani hydropower development, located on the Shire and downstream of Nkula Falls, consists of three powerhouses: Tedzani I (two Francis turbines of 11 MW), Tedzani II (two Francis turbines of 11 MW), and Tedzani III (two Francis turbines of 26 MW). Tedzani I and II stopped operating in 2001, leading to a shortfall of some 40 MW. The total capacity at Tedzani HPP is 90 MW as the units are being rehabilitated.

Kapichira

Kapichira Phase I, recently completed and located on the Shire River downstream of Tedzani, consists of two 32 MW Francis units, totaling 64 MW.

The head ponds of all three power plants located on the Shire River (Nkula Falls, Tedzani, and Kapichira) are severely affected by siltation and thus require periodical dredging.

3.1.3 Potential hydropower projects in the Zambezi River Basin

The ZRB has vast hydropower potential approaching 13,000 MW. Table 3.4. presents the projects that have been identified or evaluated according to this reference. Corrections and improvement to potential estimates have been updated as part of the study after consultation workshops with representatives from the riparian countries during 2009.

Other than the information provided in the assessment by Euroconsult Mott MacDonald (2007), no source of information has been identified for the small hydropower schemes in Angola.

The potential hydropower plants described in detail below were included in the recent regional generation planning studies or not considered on economic or environmental grounds. Little or no

Table 3.4. Potential hydropower in the Zambezi River Basin (by country)

Country	River	HP/Reservoir	Capacity (MW)	Study stage
Angola	Lumbage	1	1	n/a
Angola	Zambezi	2	4	n/a
Angola	Zambezi	3	2	n/a
Angola	Luvua	4	1	n/a
Angola	Luizavo	5	11	n/a
Angola	Ludevu	6	3	n/a
Angola	Lumache	7	1	n/a
Angola	Lufuige	8	2	n/a
Angola	Macondo	9	3	n/a
Malawi	Shire	Kapichira II	64	Feasibility
Malawi	Shire	Kholombidzo High	240	Prefeasibility
Malawi	Shire	Kholombidzo Low	217	Prefeasibility
Malawi	Shire	Mpatamanga	263	n/a
Malawi	S. Rukuru/N. Rumphi	Lower Fufu	100	n/a
Malawi	South Rukuru	Lower Fufu North	70–170	n/a
Malawi		High Fufu	85–175	n/a
Malawi		Henga Valley	20–40	n/a
Malawi	Lake Malawi/Niassa/Nyasa	Pumped storage	>1,500	n/a
Malawi	Songwe	Manolo	55–125	n/a
Malawi	Bua	Mbongozi	25–55	n/a
Malawi	Bua	Malenga	30–65	n/a
Malawi	Bua	Chizuma	110–170	n/a
Malawi	Bua	Chasonmbo	25–55	n/a
Malawi	Ruo	Zoa Falls	20–40	n/a
Malawi	Dwambazi	Chimgonda	20–50	n/a
Malawi/Tanzania	Songwe	Songwe	340	Feasibility
Mozambique	Zambezi	HCB North Bank	850	Feasibility
Mozambique	Zambezi	Mphanda Nkuwa	2,000	Financing
Mozambique	Zambezi	Boroma	444	Prefeasibility
Mozambique	Zambezi	Lupata	654	n/a
Mozambique	Zambezi	Ancuaze-Sinjal I	330–600	n/a
Mozambique	Zambezi	Chemba	1,040	n/a
Mozambique	Revubue	1	36	n/a
Mozambique	Revubue	2	110	n/a
Mozambique	Revubue	3	85	n/a
Mozambique	Luia	4	267	n/a
Mozambique	Capoche	5	60	n/a
Tanzania	Ruhuhu	Masigira	118	n/a
Tanzania	Rumakali	Rumakali	256	n/a

Continued on next page

Table 3.4. Potential hydropower in the Zambezi River Basin (by country) *(continued)*

Country	River	HP/Reservoir	Capacity (MW)	Study stage
Zambia	Kabompo	Kabompo Gorge	34	Reconstruction
Zambia	Kabompo	Chikata Falls	3.5	Reconstruction
Zambia	Lunga	West Lunga	2.5	Reconstruction
Zambia	Zambezi	Chavuma Falls	10–20	Reconstruction
Zambia	Zambezi	Katombora	n/a	Prefeasibility
Zambia	Zambezi	Victoria Falls Extension	390	n/a
Zambia	Zambezi	Kariba North Extension	360	Feasibility
Zambia	Kafue	Kafue Gorge Lower	750	Financing
Zambia	Kafue	Itezhi Tezhi	120	Financing
Zambia	Lusiwasi	Lusiwasi Extension	40	n/a
Zambia and Zimbabwe	Zambezi	Batoka Gorge	1,600	Feasibility
Zambia and Zimbabwe	Zambezi	Devils Gorge	1,200	Reconstruction
Zambia and Zimbabwe	Zambezi	Mupata Gorge	640–1,200	Reconstruction
Zimbabwe	Zambezi	Victoria Falls (Zimbabwe)	300	Prefeasibility
Zimbabwe	Zambezi	Kariba South Extension	300	Feasibility

information has been obtained on the other potential sites listed in table 3.4.

Katombora Reservoir

The Katombora reservoir, would be located some 60 kilometers upstream of Victoria Falls, and be relatively large. With a surface area of 7,733 km^2 at a full supply level of 940 meters and a live storage of six km^3, it would be intended to firm up the energy production of two large power plants at Victoria Falls: one of 390 MW on the Zambian side to replace the existing Victoria Falls power plant; and a second of 300 MW on the Zimbabwean side. Katombora would also firm up energy production at the potential Batoka Gorge and Devils Gorge developments. Development of hydropower at Katombora and Victoria Falls would have serious environmental impacts on the discharge available at the falls and therefore has not received further consideration for the foreseeable future.

Batoka Gorge

Batoka Gorge, a bilateral hydropower project between Zambia and Zimbabwe, would be located at a site 50 kilometers downstream of Victoria Falls. It would include a 181 meter dam and provide up to 800 MW of capacity each for Zambia and Zimbabwe. A full feasibility study was completed in 1993 (Batoka Joint Venture Consultants 1993). The scheme is considered a serious contender for development in the medium term.

Devil's Gorge

Another proposed bilateral project on the Zambezi, Devils Gorge (1,200 MW), would be built between the Batoka Gorge and Kariba with a capacity of 600 MW at each bank. Developing this project has been postponed in the foreseeable future due to economic unfeasibility.

Kariba Extension

Additions of 360 MW and 300 MW to the existing capacities each of the Kariba North Bank and Kariba South Bank, respectively, are proposed for the medium term. Because space for two additional units was allocated at construction time of the original plant, the extension of the Kariba North powerhouse is relatively straightforward. In the case of Kariba South, the powerhouse will have to be extended.

Mupata Gorge

Mupata Gorge, located on the Zambezi just before it flows into Mozambique territory, would also be a hydropower project shared by Zambia and Zimbabwe. It would have an installed capacity of between 640 and 1200 MW. The project would at times flood Mana Pools, a UNESCO World Heritage site located on the south bank of the Zambezi in Zimbabwe upstream of the Mupata Gorge, and is therefore not feasible with respect to environmental priorities.

Itezhi Tezhi

The Itezhi Tezhi hydropower extension, would be located at the existing dam site and consist of an underground powerhouse housing of two 60 MW Kaplan units. A feasibility study was completed in 1999 (HARZA Engineering Company 1999) and the power deficit in Zambia has put the project on the fast track for development. The Itezhi Tezhi reservoir is operated mainly for regulation of the Kafue Gorge Upper and is subject to various constraints; therefore the Itezhi Tezhi power plant would not be operated to firm up energy but rather to generate available energy in accordance with reservoir variation.

Kafue Gorge Lower

A feasibility study of developing 600 MW, with an additional bay for 150 MW, capacity in the Kafue Gorge Lower was completed in 1995 (HARZA Engineering Company 1995). In 2006 a site selection report that considered an installed capacity of 750 MW was submitted to the ZESCO (MHW Global 2006). This development is a serious contender in the medium term.

Songwe

A study of stabilization of the course of the Songwe River, which forms the border between Malawi and Tanzania, also analyzed the development of hydropower capacity (NORPLAN 2003). Dams large enough to control major floods in the Songwe River would need to be quite large, and exploiting the hydropower potential provides the opportunity to recoup the implementation costs. Three sites—Songwe I, II, and III—have been identified. The hydropower plants should be designed for combined hydropower and flood control. In the feasibility study, a range of installed capacities were considered (NORPLAN 2003). In 2009, the governments of Malawi and Tanzania investigated those projects further, assuming an installed capacity of 34 MW, 157 MW, and 149 MW for Songwe I, II, and III, respectively. Even if the three reservoirs are operated primarily for flood mitigation, each has sufficient volume in relation to inflows to firm up reservoir yield and energy production.

Rumakali

The Rumakali Hydropower Scheme would be located on the Rumakali River 85 kilometers west of Njombe in the Iringa Region of southwestern Tanzania (SwedPower and Norconsult 1998). The scheme comprises a storage dam in the river, an intake close to the dam, and a system of underground tunnels and penstock systems under the escarpment leading down to an underground power station housing three 74 MW Pelton units at the foot of the escarpment about seven kilometers from the intake. From the power station, water will be discharged back to the river via a three kilometers long tailrace tunnel ending about two kilometers upstream of the confluence with the Lufirio River. The reservoir has sufficient volume in relation to inflows to firm up reservoir yield and energy production.

Lower Fufu

A prefeasibility study of the Lower Fufu, a run-of-the-river (R-o-R) project, concentrates on the hydropower potential of the south Rukuru and north Rumphi Rivers. The study suggests that it is possible to apply the "collect and transfer" principle—that is, to combine the water resources of the two rivers, and construct an underground R-o-R power station near Chiweta. The scheme will divert a maximum of approximately 30 m^3 per second (the total of both rivers) by constructing a concrete diversion dam and intake arrangements in two places: on the south Rukuru River close to the M1-highway near Jalawe village, and on the north Rumphi approximately five kilometers upstream of the Mchenga coal mine. Two alternative systems of tunnels have been considered, both with a total length of 15 kilometers, leading down to an underground power station south of Chiweta with an installation of two 45 MW units. A 45 kilometer, 132 kV transmission line will connect to the main grid at Bwengu.

Kholombidzo

Two alternatives have been analyzed for hydropower development at Kholombidzo (Norconsult 2003). The first, High Kholombidzo HPP, would have highest regulated water level at 475.3 meter elevation. It has been suggested for hydropower development of the hydraulic head of about 75 meter between Kholombidzo falls and Toni rapids and would function as a level control for Lake Malawi/Niassa/Nyasa. Control of the outflow from Lake Malawi/Niassa/Nyasa would be accomplished through operating the power plant. In case of floods, water would be released through the flood gates at the diversion dam just upstream of the Kholombidzo Falls. This alternative would make the gated barrage at Liwonde superfluous, and the gates would need to be removed. The High Kholombidzo Dam would be located in the Shire River between the Kholombidzo Falls and Liwonde at a level that would inundate about 4.5 kilometers of the railway in the Mpimbe area, including the Shire River bridge crossing and part of the Ndala-Blantyre road. The High Kholombidzo Dam would only partially control the outflow of Lake Malawi/Niassa/Nyasa. It may increase outflow for a short period by emptying the Kholombidzo headpond, as Lake Malawi/Niassa/Nyasa would retain its natural outlet control. This would not have been the case with the original high dam, which was projected at a higher crest level that would have allowed full control of the lake drawdown and allowed for the development of a larger HPP. This original proposal was abandoned however, as it would have flooded prime agricultural land and infrastructure, displaced a large population, and increased the potential for severe flooding downstream.

The second alternative, the Low Kholombidzo HPP, with highest regulated water level at 471 meter elevation would have the same layout but with a head pond that would be 4.3 meter lower. The Low Kholombidzo HPP would not be able to regulate the level of Lake Malawi/Niassa/Nyasa since the lake outflow stops at level 471.5 meters. The existing regulating barrage at Liwonde would have to be upgraded or reconstructed for this purpose. The main dam at Kholombidzo falls would regulate the flow from the catchment between Liwonde and Kholombidzo and control the reservoir of the Low Kholombidzo HPP.

Kapichira

The second phase of the Kapichira hydroelectric power project will entail the addition of an additional 64 MW of capacity. The existing power station was designed for 128 MW but produces only 64 MW. The project will comprise mainly electromechanical installations involving the design, supply, installation, and commissioning of two 32 MW machines, transformers, switchgear, and a power transmission line that will link into the main ESCOM grid at the Blantyre West substation. Civil works for the two machines would be minimal since most were already undertaken for the two machines under the development of the first phase, commissioned in 2000.

Cahora Bassa North Bank

The Cahora Bassa North Bank is an extension of the existing development. The project consists of a new underground powerhouse on the north bank of the Zambezi River with three 283.3 MW Francis units (Norconsult 2003). A new spillway, with a design discharge of 3,600 m^3 per second and comprising two tunnels, would allow operation of the Cahora Bassa reservoir without using the present flood rule curve, which requires lowering the lake level before the high-flow period.

Mphanda Nkuwa

The Mphanda Nkuwa project site is located some 60 kilometers downstream of the Cahora Bassa

Dam. The project comprises a 101 meter high roller-compacted concrete (RCC) dam impounding a reservoir with a surface area of approximately 100 km^2. The dam will be surmounted by an integral spillway commanded by 13 radial crest gates. A surface powerhouse with an installed capacity of 1,300 MW composed of four 325 MW units would be located adjacent to the dam on the left bank (Joint Venture LI-EDF-KP 2002). Recent estimates for total capacity as been increased to 2,000 MW. However, the development of up to 2,275 MW at Mphanda Nkuwa would be possible in the future either by making provisions for future extension to the power station on the north bank at the site, or by a separate underground power station on the south bank. This would need to be accompanied by development of the Boroma project to provide regulation of fluctuating downstream river flows.

The Boroma reservoir would only be needed if Mphanda Nkuwa is developed to its full potential. If only the first 1,300 MW phase is developed, Mphanda Nkuwa will be operated as a R-o-R plant, and there would be no need for reregulation downstream. Otherwise, Mphanda Nkuwa will likely operate in midmerit or peaking mode, which would require reregulation downstream that would be provided by Boroma. In a second phase, a power plant could be installed at the site where installed capacity has not been finalized. Construction is anticipated to start in 2011.

3.1.4 SAPP energy sector development

To overcome the energy deficit experienced by several countries in the region, there is now a serious drive to build new generating capacity and rehabilitate and upgrade existing hydro and thermal power stations. Several HPPs, including the Kariba North and South and KGU, have already been refurbished. An intertie was also constructed between Songo in Mozambique and Malawi. Financing is also being sought to extend the Kariba North and South banks and Itezhi Tezhi. In addition, several generation-planning studies are either underway or were recently completed, both at the national level (such as the generation-planning study of Tanzania) and the regional level.

Two regional generation-planning studies commissioned by the World Bank—NEXANT 2007 and ECON Pöyry 2008—were recently completed. The NEXANT study considers the planning horizon 2008–25, and the ECON study considers 2005–15. Power utility members of the SAPP have developed formal and informal generation plans for systems that are either isolated or partially integrated by existing interties. This fragmented approach results in significant differences of reserve margins across countries. In addition, the overall regional reserve margin exceeds the reserve that would be needed should the regional grid be integrated. The purpose of the two studies was to evaluate a least-cost alternative that would integrate the SAPP network—including the transmission components necessary to assure the power pool integration—while maintaining an adequate reserve margin.

In the NEXANT regional load forecast, net peak demand varies from 41,400 MW in 2006 to 71,500 MW in 2025. Net generation varies from 272,200 GWh to 471,300 GWh over the same period.

As the two regional studies neared completion, ESKOM publicly announced that it was revising its load forecast upward, and that it would develop between 18,000 and 20,000 MW of nuclear power between now and 2025. Two consortiums were bidding for a 3,500 MW nuclear unit; both have pledged to develop the nuclear capacity. NEXANT revised its study in accordance with the new regional load forecast so that net peak demand varies from some 42,750 MW in 2006 to 93,560 MW in 2025. Net generation varies from 290,780 GWh to 586,900 GWh over the same period. More recently, as a result of the current global economic crisis, South Africa has shelved its nuclear expansion plan, and the regional SAPP generation plan has reverted to the prenuclear option.

The NEXANT study is the most up-to-date with respect to hydropower development in the ZRB. It has therefore been taken as the basis for future hydropower projects in the basin for the MSIOA study. Table 3.5. presents the base case and alternate least-cost scenarios. The base case represents the aggregate generating units added on all national generation plans. The alternative case represents the least-cost alternative to meet future capacity and energy demand from a fully interconnected SAPP transmission network. The major difference

Table 3.5. Future hydropower projects in the Zambezi River Basin (included in MSIOA)

Project	Status	Utility	River	Country	Type	Base case		Alternative case	
						Capacity (MW)	Operating year	Capacity (MW)	Operating year
Tedzani 1 & 2	refurbishment	ESCOM	Shire	Malawi	Pondage	40	2008	40	2008
Kariba North	refurbishment	ZESCO	Zambezi	Zambia	Reservoir	120	2008–2009	120	2008
Kafue Gorge Upper	refurbishment	ZESCO	Kafue	Zambia	Pondage	150	2009	150	2009
Kapichira II	extension	ESCOM	Shire	Malawi	Pondage	64	2010	64	2010
Kariba North	extension	ZESCO	Zambezi	Zambia	Reservoir	360	2010	360	2012
HCB North Bank	extension	HCB	Zambezi	Mozambique	Reservoir	n/a	n/a	850	2012
Itezhi Tezhi	extension	ZESCO	Kafue	Zambia	Reservoir	120	2013	120	2013
Kariba South	extension	ZESA	Zambezi	Zimbabwe	Reservoir	300	2014	300	2014
Songwe I, II & III	new project	ESCOM	Songwe	Malawi, Tanzania	Reservoirs	340	2014–2016	340	2024
Batoka Gorge South	new project	ZESA	Zambezi	Zimbabwe	Pondage	800	2017	800	2023–2024
Batoka Gorge North	new project	ZESCO	Zambezi	Zambia	Pondage	800	2017	800	2023–2024
Kafue Gorge Lower	new project	ZESCO	Zambezi	Zambia	Pondage	750	2017	750	2017–2022
Mphanda Nkuwa	new project	EdM	Zambezi	Mozambique	Pondage	1,300	2020	2,000	2024
Lower Fufu	new project	ESCOM	S. Ruhuru	Malawi	Run-of-River	n/a	n/a	100	2024
Kholombidzo	new project	ESCOM	Shire	Malawi	Pondage	n/a	n/a	240	2025
Rumakali	new project	TANESCO	Rumakali	Tanzania	Reservoir	222	2022	256	n/a

Source: NEXANT 2008.
Note: The estimated capacity of Kafue Gorge Lower is 600 MW with an additional bay for 150 MW.

between the scenario (other than the operating years) are that Rumakali will be part of the base scenario only, while the Cahora Bassa North Bank, Lower Fufu, and Kholombidzo are included only in the least-cost alternative. The base case scenario presents the aggregate hydropower addition considered in the national power generation plans of the eight riparian countries of the ZRB. Only those HPPs considered in those national generation plans are included in table 3.5.

Since the NEXANT study reports were issued, more studies have been completed or are ongoing. They consider project characteristics different than those adopted in the NEXANT study. For such cases, such as Songwe in Malawi and Mphanda Nkuwa in Mozambique, the latest project data are presented in table 3.5.

Several new initiatives will have to be built or existing ones strengthened for the SAPP to act as a power pool.

3.1.5 Strengths and challenges of hydropower development in the Zambezi River Basin

Strengths

With some 5,000 MW of developed capacity, 6,634 MW proposed for development before 2025, and several other major sites identified for development in the longer term, hydropower is one of the major resources of the Basin.

Hydropower generated from water is cleaner than fossil fuel sources and therefore contributes to the goal of the World Bank and other institutions of a transition to a low-carbon economy. The source is also renewable and does not consume fuel contrary to thermal plants. Operational costs are minimal since they do not involve fuel spending and the technology is robust and requires less maintenance than thermal and nuclear.

One major drawback of thermal and nuclear power plants is that they cannot respond instantaneously to a change in load. Instead, they have an inertia built into generation that translates into a slow response. These units are therefore best suited to respond to base load. Hydropower units on the other hand, can respond instantaneously when they are running at “speed-no-load.” In this mode of operation, a hydropower unit runs at synchronous speed without being connected to the system. It wastes some water. As the load picks up, the unit can be connected nearly instantaneously. Hydropower units are therefore ideally suited to operate in the midmerit and peak zones of the load curve. The alternative is to install units running on distillates—such as gas turbines and diesel—whose capital cost is relatively cheap but whose operating costs are high.

The construction of reservoirs may increase navigation, promote the development of commercial fisheries and prevent or mitigate disastrous flooding. The major reservoirs, Lake Kariba and Lake Cahora Bassa, are already built. Future developments will comprise much smaller reservoirs, the largest of which will be Mphanda Nkuwa, with a storage capacity of 2.32 km^3 and a surface area of 96.5 km^2 at full supply level. By comparison, Cahora Bassa has a storage capacity of 51.75 km^3 and a surface area of 3,040 km^2 at full supply level.

Challenges

Hydropower depends on river flows, which vary seasonally and cyclically with relatively little forecast. Power generation will therefore vary along with flow, especially in the ZRB. Reservoirs can mitigate that effect somewhat by smoothing out

Table 3.6. Hydropower – strengths and challenges

Subbasin	Strengths	Challenges
Upper Zambezi, from Kabompo to Barotse (13 to 9)	Only potential for small HPP	There is no site for medium to large hydropower in this region.
Kafue (7)	Extensive management of Kafue River Basin	Operation of the Itezhi Tezhi reservoir affects the Kafue Flats wetland. A minimum release of 25 m^3/s as e-flow has been prescribed at Itezhi Tezhi except in March when the minimum release should be 300 m^3/s. It is not always possible to adhere to these flows.
Kariba (6)	Extensive cooperation between governments of Zambia and Zimbabwe on managing Kariba Dam (i.e., Zambezi River Authority)	The Kariba spillway is located on top of the dam thus preventing restoration of natural flooding for the potential benefit of downstream riparian stakeholders. The Kariba net evaporation represents 16 percent of the total inflow into the lake. The Devils Gorge HPP development lacks financial feasibility.
Shire River and Lake Malawi/Niassa/Nyasa (3)		The HPPs on the Shire River are subject to heavy siltation that prevents them from operating to full capacity requiring periodic maintenance. It is possible that other developments in the Lake Malawi/Niassa/Nyasa catchment, especially Songwe, be affected.
Tete (2)	Growing cooperation between management of Cahora Bassa and Kariba Dams	Operation and opening of the spillways of the Cahora Bassa Dam can at times flood areas in the Zambezi floodplain at Tete leading to negative impact on encroaching settlements. Flooding is much less severe than under natural conditions prior to the construction of the dam. As a result of flow regulation from Cahora Bassa Dam (and Kariba Dam to a certain extent), natural floods that are beneficial to the Zambezi Lower Delta have been reduced, threatening the environmental sustainability of the Delta. Cahora Bassa net evaporation represents 4 percent of the total inflow into the lake.

seasonal variation and, in the case of large reservoirs such as Lake Kariba and Lake Cahora Bassa, periodicity. Yet the flow series observed on the Zambezi River and the Kafue River show extended periods of above and below normal flow. The discharges of the Zambezi River have been measured at Victoria Falls since the late 1800s and more precisely since 1907. The flow was below normal from 1907 to 1924, then normal from 1924 to 1947, above normal from 1947 to 1981, and finally below normal from 1981 to date. The Kafue River behaves in a similar fashion. On the other end, the inflows to Lake Malawi/Niassa/Nyasa analyzed since 1954 show much shorter cycles that may vary from three to ten years, as the subbasin is in a wetter zone.

Capital costs for hydropower are high compared with thermal and nuclear options, mainly due to intensive civil works. This presents a major challenge for the development of hydropower in the Basin, given the difficulties in securing large-scale financing. Depreciation is generally calculated over a long period (typically 50 years), however, and the interest rate offered is favorable. Compared to thermal and nuclear, hydropower projects also require long lead times from studies to power commissioning—typically from 10 to 15 years.

With the operation of reservoirs, especially large ones, the flow regime changes to a regulated flow that provides less variation than the natural flow. A new flow regime may have serious environmental implications for downstream areas, economic activity, ecosystems, and population.

Water losses by evaporation in the area under study, especially in the large reservoirs, can be large and represent a significant amount of the basin water balance.

Reservoirs trap sediments which has two major detrimental effects. First, sediment filling affects the operation of the power plant and requires remedial measures—such as reservoir flushing and dredging—with associated maintenance costs. It may also severely affect downstream reaches where, during the wet season, river bank erosion occurs for which the deposition of sediment from upstream reaches can no longer compensate.

A reservoir will submerge the river valley and thus the resources within. Fertile agricultural land can be lost and people living in the valley or near the intended perimeters of the reservoir are often affected, sometimes displaced. With the creation of a man-made lake, access to natural resources and ecosystem services for livelihoods is also negatively impacted.

3.1.6 Opportunities and constraints for hydropower development in the Zambezi River Basin

Three of the countries where medium to large hydropower can be developed suffer frequent critical energy shortages and must rapidly expand their power pool. It is therefore an opportune time to develop these resources (table 3.7).

At the time Kariba and Cahora Bassa dams were designed and built, the common objective was to develop hydropower without due consideration for multi-purpose usage or detrimental effects to other sectors. Although a large-scale hydropower development is proposed in the SAPP region over the medium term, the benefits for isolated rural communities may take longer since extension of the grid may be slowed due to a number of social, physical and economic factors. There is potential for small-scale hydropower development in the Basin, particularly in areas that are far from transmission lines.

Small R-o-R hydropower units can be important non-polluting renewable sources of energy at a considerably lower cost than wind or solar energy. Startup costs depend on the size and design of the system, but for very small systems investment costs start from $300 per kW. Small hydropower units can be integrated with the local power grid if excess energy is produced. Site selection is important and power delivery may be low during dry periods unless ponds are considered. The major areas for considerations are those in the upper part of the Basin. These are the Kabompo (13), the Upper Zambezi (12) and the Lungúe Bungo (11) subbasins; the northern part of the Kafue (7) and Luangwa (5) subbasins; and the subcatchment of Lake Malawi/Niassa/Nyasa (3).

Optimal operation of the Kariba and Cahora Bassa reservoirs is dependent on the ability to forecast floods. The Zambezi River Authority (ZRA) face challenges in forecasting floods for optimal operation of Kariba Dam in the medium to long-term. HCB has developed a tool for forecasting

Table 3.7. Hydropower – opportunities and constraints

Subbasin	Opportunities	Constraints
Upper Zambezi, from Kabompo to Barotse (13 to 9)	Only small HPPs are planned.	None.
Kariba (6)	The development of the Batoka Gorge will significantly increase power production in Zambia and Zimbabwe, especially if it is operated conjunctively with Kariba. Implementation of conjunctive operation between the Kariba system and other systems in the Basin.	Devils Gorge HPP development lacks financial viability.
Kafue (7)	Major HPP developments are considered at Itezhi Tezhi and KGU. Implementation of conjunctive operation between the Kafue system and other systems in the Basin.	Impacts on wetlands and irrigation development.
Shire River and Lake Malawi/Niassa/Nyasa (3)	Several HPP developments are considered in the Lake Malawi/Niassa/Nyasa catchment (Rumakali, Songwe, and Lower Fufu) as well as the construction of Kholombidzo and extension of Kapichira on the Shire. Malawi suffers a large generation deficit. Implementation of conjunctive operation between the Shire/Lake Malawi/Niassa/Nyasa system and other systems in the Basin.	The HPPs on the Shire River are and would be subject to heavy siltation that prevents them from operating to their full capacity and requires periodic maintenance. It is possible that other developments in the Lake Malawi/Niassa/Nyasa catchment, especially Songwe, may also be affected.
Tete (3)	The development of Mphanda Nkuwa downstream from Cahora Bassa will provide supplementary power to the region. The development of Cahora Bassa North will permit the generation of peak power for the SAPP. Remedial measures have been proposed to release artificial floods from Cahora Bassa to improve conditions in the Delta. Implementation of conjunctive operation between the Cahora Bassa system and other systems in the Basin.	Investments have been lacking due to tremendous costs and time needed for exchanging shares of ownership of Cahora Bassa between Portugal and Mozambique.

floods into the Cahora Bassa reservoir. However, the tool could be greatly improved if information from upstream parts of the river could become available and on a regular basis. Developing an agreement and system for exchanging hydrometric information between the operators of ZRA and HCB could bring a multitude of benefits.

Countries rich in hydropower resources often face difficulty in raising the necessary large amounts of capital, especially when there are multi-sector development requirements. A portion of generated energy is reserved for export to countries that are in a better financial position, however, which can assist them in securing the required financing. In this respect, recent decisions by South Africa to develop a large pool of nuclear generation can directly impact how financially viable and attractive it would be to develop hydropower in the Basin.

3.1.7 Characteristics and parameters of hydropower plants

Water usage and energy production were simulated as part of the MSIOA so as to properly evaluate the productive and economic benefits of various options. To calculate energy production, a number of parameters related to a reservoir, generating units, and spillway must be defined (as described in volume 4). Those parameters have been obtained from previous studies in the case of existing developments and from prefeasibility or feasibility studies in the case of future developments.

The characteristics of the various projects are presented in tables 3.8. through 3.54.

Batoka Gorge (projected)

Table 3.8. Batoka Gorge – storage, area, outlet and elevation

Storage (million m^3)	Area (km^2)	Outlet capacity			Elevation (m)	Note
		Turbines (m^3/s)	Spillway (m^3/s)	Total (m^3/s)		
51	3.8	629	0	630	640	
294	9.2	785	0	785	680	
511	12.5	867	0	867	700	
1,161	20.2	1,027	0	1,028	740	
1,294	21.6	1,052	0	1,052	746	MOL
1,680	25.6	1,111	7,263	8,374	762	FSL
1,754	26.4	1,111	20,000	21,131	765	MFL

Source: Batoka Joint Venture Consultants 1993; ZRA 2002.
Note: MOL: minimum operating level; FSL: full supply level; MFL: minimum flow level.

Table 3.9. Batoka Gorge – turbine characteristics

Installed capacity (MW)	1,600
No. of units	8
Rated head, Hr (m)	166.56
Rated power, Pr (MW)	205.12
Rated discharge, Qr (m^3/s)	138.82
Average efficiency	0.88
Plant rated discharge (m^3/s)	1,111

Source: Batoka Joint Venture Consultants 1993; ZRA 2002.

Table 3.10. Batoka Gorge – tailwater rating

Discharge (m^3/s)	Tailwater level plus losses (m)
0	585.4
479	593.2
719	594.3
959	595.6
1,111	595.8
1,319	597.1
1,518	597.9
3,000	601.4
9,000	609.3
12,000	612.0
15,000	614.0

Source: Batoka Joint Venture Consultants 1993; ZRA Kariba (Existing HPP) 2002.

Kariba (existing and extension)

Table 3.11. Kariba – storage, area, outlet, elevation and peak power

Storage (million m^3)	Area (km^2)	Outlet capacity			Elevation (m)	Note	Peak power (MW)
		Turbines (m^3/s)	Spillway (m^3/s)	Total (m^3/s)			
24	921	1,706	0	1,706	470.0	LSL	1,269
54	4,354	1,771	0	1,771	475.5	MOL	1,402
11,278	4,608	1,801	0	1,801	478.0		1,462
18,262	4,760	1,819	7,640	9,459	479.5		1,470
23,040	4,857	1,832	7,862	9,694	480.5		1,470
30,408	4,991	1,850	8,168	10,018	482.0		1,470
37,989	5,126	1,866	8,786	10,652	483.5		1,470
45,778	5,261	1,884	8,786	10,670	485.0		1,470
53,788	5,395	1,902	9,068	10,969	486.5		1,470
64,798	5,577	1,925	9,445	11,370	488.5	FSL	1,470

Source: Shawinigan Engineering and Hidrotecnica Portuguesa 1990. Peak power estimated by BRLi-NIRAS as part of MSIOA.
Note: LSL: low supply level; MOL: minimum operating level; FSL: full supply level.

Table 3.12. Lake Kariba – flood rule curve

Month	Month-end reservoir level (m)	Month-end reservoir storage (million m^3)
Oct	486.5	53,788
Nov	486.0	50,769
Dec	485.5	48,204
Jan	484.0	40,666
Feb	485.4	47,696
Mar	487.8	60,221
Apr	488.5	64,798
May	488.5	64,798
Jun	488.5	64,798
Jul	488.0	61,662
Aug	487.5	58,808
Sep	487.0	56,054

Source: ZRA 2002.

Table 3.13. Kariba HPP – turbine characteristics

	Kariba North		Kariba South		Total
	Original	Actual	Original	Actual	Actual
Installed capacity (MW)	600	720	666	750	1,470
Rated discharge (m^3/s)	744	893	800	901	1,794
Rated net head (calculated)	91.3		94.3		92.8
Assumed efficiency rating	0.9		0.9		
Assumed overall efficiency					0.89

Source: NIRAS 2003.

Table 3.14. Lake Kariba – tailwater rating

Discharge (m^3/s)	Tailwater level + losses (m)
—	375.95
479	383.70
719	384.86
959	386.19
1,319	387.67
1,518	388.48
3,000	391.96
9,000	399.87
12,000	402.55
15,000	404.55

Source: Shawinigan Engineering and Hidrotecnica Portuguesa 1990.

Table 3.15. Lake Kariba future HPP – storage, area, outlet, elevation and peak power

		Outlet capacity					
Storage (million m^3)	Area (km^2)	Turbines (m^3/s)	Spillway (m^3/s)	Total (m^3/s)	Elevation (m)	Note	Peak power (MW)
24	921	2,671	0	2,671	470.0	LSL	2,021
54	4,354	2,771	0	2,771	475.5	MOL	2,231
11,278	4,608	2,825	0	2,825	478.0		2,327
18,262	4,760	2,851	7,640	10,491	479.5		2,340
23,040	4,857	2,873	7,862	10,735	480.5		2,340
30,408	4,991	2,899	8,168	11,067	482.0		2,340
37,989	5,126	2,930	8,786	11,716	483.5		2,340
45,778	5,261	2,951	8,786	11,737	485.0		2,340
53,788	5,395	2,983	9,068	12,050	486.5		2,340
64,798	5,577	3,021	9,445	12,466	488.5	FSL	2,340

Source: Calculated as part of MSIOA for Kariba North refurbishment and addition of 660 MW.
Note: LSL: low supply level; MOL: minimum operating level; FSL: full supply level.

Table 3.16. Kariba future HPP – characteristics

Installed capacity (MW)	2,340
Rated discharge (m³/s)	2,861
Rated net head (calculated)	92.8
Assumed overall efficiency	0.89

Source: Calculated in this study for Kariba North refurbishment and addition of 660 MW.

Itezhi Tezhi (existing and extension)

Table 3.17. Itezhi Tezhi Reservoir – storage, area, outlet and elevation

Storage (million m³)	Area (km²)	Outlet capacity (m³/s)	Elevation (m)	Note
612	84	400	1,005.0	
699	90	1,500	1,006.0	MOL
1,003	113	2,000	1,009.0	
1,377	138	2,600	1,012.0	
1,836	167	3,200	1,015.0	
2,387	203	3,800	1,018.0	
3,291	253	4,200	1,022.0	
4,424	314	4,800	1,026.0	
6,008	392	5,600	1,030.5	FSL
6,204	404	6,000	1,031.0	

Source: Shawinigan Engineering and Hidrotecnica Portuguesa 1990.
Note: MOL: minimum operating level; FSL: full supply level.

Table 3.18. Itezhi Tezhi reservoir – flood rule curve

Month	Month-end level (m)	Month-end volume (million m³)
Oct	1,024.3	3,942
Nov	1,023.6	3,744
Dec	1,024.1	3,886
Jan	1,025.4	4,254
Feb	1,026.8	4,706
Mar	1,027.7	5,022
Apr	1,029.6	5,691
May	1,030.5	6,008
Jun	1,030.5	6,008
Jul	1,030.0	5,832
Aug	1,028.0	5,128
Sep	1,026.0	4,424

Source: ZESCO.

Table 3.19. Itezhi Tezhi future HPP – characteristics

Installed capacity (MW)	120
Rated head, Hr (m)	40
Total rated discharge, Qr (m^3/s)	312
Average efficiency	0.89
Friction losses (%)	2
Tailwater level, Qr (m)	986
Gross head (m)	40.8
Reservoir level, Hr (m)	1,026.8
Head loss (m)	0.8

Source: HARZA Engineering Company 1999.

Table 3.20. Itezhi Tezhi future HPP – tailwater rating

Discharge (m^3/s)	Tailwater level + losses (m)
0	980.8
310	986.8
1,158	990.1
1,575	991.2
2,110	992.4
2,631	993.3
3,309	994.4
4,031	995.4
5,214	996.8
6,172	997.8

Source: HARZA Engineering Company 1999.

Kafue Flats

Table 3.21. Kafue Flats – storage, area, outlet and elevation

Storage (million m³)	Area (km²)	Outlet capacity (m³/s)	Elevation (m)
15	30	75	976.0
77	114	95	977.0
303	405	200	978.0
989	950	300	979.0
2,143	1,340	440	980.0
4,853	1,710	725	981.8
6,174	1,810	840	982.5
7,563	1,890	975	983.3
9,498	1,975	3,200	984.3
10,887	2,055	4,200	985.0

Source: Shawinigan Engineering and Hidrotecnica Portuguesa 1990.

Kafue Gorge Upper (existing)

Table 3.22. Kafue Gorge Upper Reservoir – storage, area, outlet and elevation

Storage (million m³)	Area (km²)	Outlet capacity (m³/s)	Elevation (m)	Note
19.5	35	233	973.0	
39.8	47	291	973.5	
68.9	70	350	974.0	
110.6	98	408	974.5	
170.4	142	466	975.0	
262.5	235	525	975.5	
423.1	430	1,166	976.0	
709.0	725	2,333	976.5	
785.0	805	3,500	976.6	FSL
1177.5	1,175	4,900	977.0	

Source: ZRA 2007.
Note: FSL: full supply level.

Table 3.23. Kafue Gorge Upper Reservoir – flood rule curve

Month	Month-end level (m)	Month-end volume (million m³)
Oct	975.4	244.1
Nov	975.4	244.1
Dec	975.9	391.0
Jan	976.5	709.0
Feb	977.0	1,177.5
Mar	977.0	1,177.5
Apr	977.0	1,177.5
May	976.5	976.5
Jun	975.9	391.0
Jul	975.4	244.1
Aug	975.4	244.1
Sep	975.4	244.1

Source: ZESCO.

Table 3.24. Kafue Gorge Upper HPP – characteristics

Installed capacity (MW)	990
Headloss (m)	5
Average efficiency	0.89
Penstock capacity (m³/s)	290

Source: Scott Wilson Piésold 2003b.

Table 3.25. Kafue Gorge Upper HPP – tailwater rating

Discharge (m³/s)	Tailwater level + losses (m)
0	584.0
115	584.6
212	585.8
400	587.1
615	588.2
820	589.0
1,590	591.4

Source: Scott Wilson Piésold 2003b.

Kafue Gorge Lower (projected)

Table 3.26. Kafue Gorge Lower Reservoir – storage, area, outlet and elevation

Storage (million m³)	Area (km²)	Elevation (m)	Note
0	0.26	503.4	
5.15	0.42	518.6	
10.95	0.55	530.0	MOL
12.93	0.6	533.9	
24.01	0.85	549.1	
39.12	1.13	564.4	
59.08	1.49	579.7	
62.84	1.53	582.0	FSL
83.52	1.72	594.9	
112.98	2.14	610.2	

Source: HARZA Engineering Company 1995; MHW 2006.
Note: MOL: minimum operating level; FSL: full supply level.

Table 3.27. Kafue Gorge Lower – tailwater rating

Discharge (m³/s)	Tailwater level + losses (m)
0	386.0
88	386.7
177	387.1
265	387.7
420	388.4
500	388.7
1,000	390.1
1,500	391.1

Source: HARZA Engineering Company 1995; MHW 2006.

Cahora Bassa (existing and extension)

Table 3.28. Cahora Bassa HPP – storage, area, discharge, outlet, elevation and peak power

Storage (million m³)	Area (km²)	Turbine discharge (m³/s)	Spillway 1 discharge (m³/s)	Spillway 2 discharge (m³/s)	Outlet capacity (m³/s)	Elevation (m)	Note	Peak power (MW)
12	680	2,102	9,871	—	11,973	291		1,686
32	856	2,155	10,284	—	12,439	295	MOL	1,806
865	900	2,173	10,800	—	12,973	296		1,835
5,840	1,120	2,234	10,894	—	13,128	301		1,986
12,060	1,385	2,300	11,366	—	13,667	306		2,075
19,640	1,650	2,367	11,744	—	14,111	311		2,075
28,640	1,980	2,435	11,830	—	14,265	316		2,075
39,320	2,310	2,503	12,262	2	14,766	321		2,075
51,750	2,675	2,565	12,608	272	15,445	326	FSL	2,075
66,010	3,040	2,633	13,504	802	16,940	331		2,075

Sources: Shawinigan Engineering and Hidrotecnica Portuguesa 1990. Peak power estimated by BRLi-NIRAS as part of MSIOA.
Note: MOL: minimum operating level; FSL: full supply level.

Table 3.29. Cahora Bassa Reservoir – upper rule curve

Month	Reservoir level (m)	Reservoir storage (million m³)
Oct	326.0	51,733
Nov	326.0	51,733
Dec	323.0	44,072
Jan	320.8	38,867
Feb	321.4	40,253
Mar	324.7	48,332
Apr	328.4	58,346
May	329.0	60,069
Jun	329.0	60,069
Jul	328.0	57,213
Aug	326.0	51,733
Sep	326.0	51,733

Source: HCB.

Table 3.30. Cahora Bassa HPP – characteristics

No. of units\	5
Generator power (MW)	415
Installed capacity (MW)	2,075
Rated head,Hr (m)	103.5
Rated discharge, Qr (m^3/s)	452
Average efficiency	0.89
Head loss (m)	1.5
Penstock capacity (m^3/s)	2,260

Source: HCB.

Table 3.31. Cahora Bassa HPP – tailwater rating

Discharge (m^3/s)	Tailwater level + losses (m)
—	194.0
500	198.9
1,000	201.1
2,000	204.3
3,000	206.9
5,000	211.1
8,000	216.1
10,500	221.5
15,000	226.1
22,000	232.0

Source: HCB.

Cahora Bassa with Cahora Bassa North Bank Powerhouse (HCB)

Table 3.32. Cahora Bassa with HCB HPP– storage, area, discharge, outlet, elevation and peak power

Storage (million m³)	Area (km²)	Turbine discharge (m³/s)	Spillway 1 discharge (m³/s)	Spillway 2 discharge (m³/s)	Outlet capacity (m³/s)	Elevation (m)	Note	Peak power (MW)
12	680	3,570	9,871	—	13,441	291		2,376
32	856	3,661	10,284	—	13,945	295	MOL	2,545
865	900	3,689	10,800	—	14,489	296		2,587
5,840	1,120	3,794	10,894	—	14,688	301		2,799
12,060	1,385	3,907	11,366	—	15,273	306		2,925
19,640	1,650	4,021	11,744	—	15,765	311		2,925
28,640	1,980	4,135	11,830	—	15,965	316		2,925
39,320	2,310	4,249	12,262	2	16,513	321		2,925
51,750	2,675	4,356	12,608	272	17,237	326	FSL	2,925
66,010	3,040	4,472	13,504	802	18,778	331		2,925

Source: Shawinigan Engineering and Hidrotecnica Portuguesa 1990. HCB Peak power estimated by BRLi-NIRAS as part of MSIOA.
Note: MOL: minimum operating level; FSL: full supply level.

Table 3.33. Cahora Bassa with HCB HPP – characteristics

Installed capacity (MW)	2,925
Rated head, Hr (m)	103.5
Average efficiency	0.89

Source: HCB.

Mphanda Nkuwa (projected)

Table 3.34. Mphanda Nkuwa – storage, area, outlet and elevation

Storage (million m³)	Area (km²)	Outlet capacity (m³/s)	Elevation (m)	Note
2,324	96.5	33,200	207	FSL

Source: H13 Joint Venture LI-EDF-KP 2002.
Note: FSL: full supply level.

Table 3.35. Mphanda Nkuwa HPP – characteristics

Installed capacity (MW)	2,000
Gross head (m)	68.7
Head loss (m)	1.7
Rated head (m)	67
Average efficiency	0.89
Rated flow (m^3/s)	2,173
Normal tailwater level – 2,200 m^3/s (m)	138.3
Tailwater + head loss (m)	140

Source: H13 Joint Venture LI-EDF-KP 2002.

Rumakali (projected)

Table 3.36. Rumakali HPP – storage, area and elevation

Storage (million m^3)	Area (km^2)	Elevation (m)	Note
0	4.1	2,025	MOL
256	13.2	2,055	FSL

Source: SwedPower and Norconsult 1998.
Note: MOL: minimum operating level; FSL: full supply level.

Table 3.37. Rumakali HPP – characteristics

Installed capacity (MW)	256
No. of units	3
Gross head (m)	1,294.50
% head loss (assumed)	1
Head loss (m)	13
Net head (m)	1,281.50
Maximum discharge (m^3/s)	19.05
Average efficiency	0.9
Tailwater level (m)	750
Tailwater level + head loss (m)	763
Mean flow at dam site (m^3/s)	12.2
Drainage area (km^2)	392

Source: SwedPower and Norconsult 1998.

Songwe I (projected)

Table 3.38. Songwe I Upper Reservoir – storage, area and elevation

Storage (million m^3)	Area (km^2)	Elevation (m)	Note
0	0.0	1,200	LSL
40	0.8	1,210	
100	2.4	1,220	
165	5.2	1,230	
275	10.6	1,240	
460	19.4	1,250	
520	30.0	1,255	FSL
770	35.0	1,260	
950	45.3	1,265	

Source: NORPLAN 2003.
Note: LSL: low supply level; FSL: full supply level.

Table 3.39. Songwe I Upper Reservoir – rule curve

Month	Storage (%)	Reservoir storage (million m^3)
Oct	65	338
Nov	50	260
Dec	30	156
Jan	0	—
Feb	0	—
Mar	15	78
Apr	80	416
May	90	468
Jun	95	494
Jul	100	520
Aug	100	520
Sep	85	442

Source: NORPLAN 2003.

Table 3.40. Songwe I HPP – characteristics

Installed capacity (MW)—Dept. of Energy Malawi	34
No. of units	3
Efficiency (reservoirs operated for flood control)	0.87
Turbine discharge (m^3/s)	47
High reservoir water level (HRWL) (m)	1,255.0
Low reservoir water level (LRWL) (m)	1,200.0
Tailwater level (m)	1,165.0
Tailwater level + Losses (m)	1,165.4
Rated head—Hr (assumed as Hmax/1.25)	71.7
Hmin/Hr is below turbine operating range of 0.65	0.48
LRWL (m) corrected for turbine operation range	1,212.0
Average unregulated discharge (m^3/s)	27.1

Source: NORPLAN 2003.

Songwe II (projected)

Table 3.41. Songwe II Middle Reservoir – storage, area and outlet

Storage (million m^3)	Area (km^2)	Elevation (m)	Note
0	0.0	1,040	LSL
15	0.3	1,060	
40	0.9	1,080	
85	2.4	1,100	
150	5.0	1,120	
300	10.1	1,140	
420	16.0	1,150	FSL
600	21.1	1,160	

Source: NORPLAN 2003.
Note: LSL: low supply level; FSL: full supply level.

Table 3.42. Songwe II Middle Reservoir – rule curve

Month	Storage (%)	Reservoir storage (million m^3)
Oct	65	273
Nov	50	210
Dec	30	126
Jan	0	—
Feb	0	—
Mar	15	63
Apr	80	336
May	90	378
Jun	95	399
Jul	100	420
Aug	100	420
Sep	85	357

Source: NORPLAN 2003.

Table 3.43. Songwe II HPP – characteristics

Installed capacity (MW)	157
No. of units	3
Efficiency (reservoirs operated for flood control)	0.87
Turbine discharge (m^3/s)	57
High reservoir water level (HRWL) (m)	1,150
Low reservoir water level (LRWL) (m)	1,050
Tailwater level (m)	825
Tailwater level + losses (m)	827.3
Hr (assumed as Hmax/1.25)	258.2
Hmin/Hr	0.86
Average unregulated discharge (m^3/s)	34.2

Source: NORPLAN 2003.

Songwe III (projected)

Table 3.44. Songwe III Lower Reservoir – storage, area and elevation

Storage (million m^3)	Area (km^2)	Elevation (m)	Note
0	0.0	700	LSL
10	0.6	710	
20	1.1	720	
35	1.7	730	
55	2.6	740	
85	3.5	750	
125	4.9	760	
185	6.5	770	
260	8.5	780	
350	11.1	790	FSL

Source: NORPLAN 2003.
Note: LSL: low supply level; FSL: full supply level.

Table 3.45. Songwe III Lower Reservoir – rule curve

Month	Storage (m)	Reservoir storage (million m^3)
Oct	65	228
Nov	50	175
Dec	30	105
Jan	0	0
Feb	0	0
Mar	15	53
Apr	80	280
May	90	315
Jun	95	333
Jul	100	350
Aug	100	350
Sep	85	298

Source: NORPLAN 2003.

Table 3.46. Songwe III HPP – characteristics

Installed capacity (MW)	149
No. of units	3
Efficiency (reservoirs operated for flood control)	0.87
Turbine discharge (m^3/s)	68
High reservoir water level (HRWL) (m)	790
Low reservoir water level (LRWL) (m)	700
Tailwater level (m)	527
Tailwater level + losses (m)	528.7
Hr (assumed as Hmax/1.25)	209
Hmin/Hr	0.82
Average unregulated discharge (m^3/s)	39.3

Source: NORPLAN 2003.

Lower Fufu (projected)

Table 3.47. Lower Fufu HPP – characteristics

Power plant	
No. of units	2
Installed capacity	90
Design flow	30
Net head	336

Source: Norconsult 1996.

Kholombidzo (projected)

Table 3.48. Lake Malawi/Niassa/Nyasa and Liwonde

Lake Malawi/Niassa/Nyasa				Liwonde	
Storage (million m^3)	**Area (km^2)**	**Outlet capacity (m^3/s)**	**Elevation (m)**	**Natural headloss (m)**	**Level (m)**
0	28,760	0	471.5	0.40	471.10
20,420	28,760	49	472.21	0.80	471.41
57,520	28,760	196	473.5	1.35	472.15
71,900	28,760	287	474.0	1.48	472.52
86,280	28,760	393	474.5	1.55	472.95
100,660	28,760	512	475.0	1.58	473.42
115,040	28,760	643	475.5	1.58	473.92
129,420	28,760	788	476.0	1.58	474.42
143,800	28,760	944	476.5	1.58	474.92
154,729	28,760	1,071	476.88	1.58	475.30

Source: Norconsult 2003.

Table 3.49. Kholombidzo Reservoir and HPP – storage, area, outflow, elevation and peak power

Kholombidzo Reservoir					
Storage (million m³)	Area (km²)	Maximum outflow (m³/s)	Elevation (m)	Note	Peak capacity (MW)
0	0		457.00		0
443	91.9	1,126	471.00	MOL	226
470	93.2	1,268	471.41		227
524	96.7	1,567	472.15		230
595	103.2	1,961	472.95		233
643	108.8	2,229	473.42		234
701	116.7	2,546	473.92		236
766	126.9	2,899	474.42		237
840	140.0	3,288	474.92		239
903	152.1	3,609	475.30	FSL	240

Source: Norconsult 2003.

Note: MOL: minimum operating level; FSL: full supply level.

Table 3.50. Kholombidzo HPP – characteristics

Power plant	
No. of units	4
Installed capacity (MW)	240
Maximum discharge (m³/s)	372
Gross head (m)	75.3
Net head (m)	72
Nominal TWL (m)	400
Headloss (m)	3.3
TWL + losses (m)	403.3

Source: Norconsult 2003.

Table 3.51. Kholombidzo HPP – tailwater rating

Discharge (m³/s)	Level (m)
	394.5
6	396.0
72	398.0
281	400.0
365	400.5
465	401.0
716	402.0
1,462	404.0
2,601	406.0
4,219	408.0

Source: Norconsult 2003.

Nkula Falls (existing)

Table 3.52. Nkula Falls HPP – characteristics

	Nkula A	Nkula B	Total
Installed capacity (MW)	24	100	124
Rated discharge (m^3/s)	51	195	246
Net head	53.7	58.5	57.6
Average efficiency	0.86	0.86	0.86
Reservoir surface area (km^2)			0.4

Source: NIRAS 2003.

Tedzani (existing)

Table 3.53. Tedzani HPP– characteristics

Power plant	I + II	III	Total
Installed capacity (MW)	40	50	90
Rated discharge (m^3/s)	120	156	276
Average efficiency	0.86	0.86	0.86
Net head	39.5	38	38.7
Reservoir surface area (km^2)			0.8

Source: NIRAS 2003.

Kapichira (existing and extension)

Table 3.54. Kapichira HPP – characteristics

	Phase I	Phase II	Total
Plant capacity (MW)	64	64	128
No. of turbines	2	2	4
Turbine discharge (m^3/s)	67	67	134
Gross head (m)	58.04	58.04	58.04
Net head	55.33	55.33	55.33
Head loss (m)	2.71	2.71	2.71
Head loss (%)	5	5	5
Average efficiency	0.88	0.88	0.89
Average headpond level (m)	145.3	145.3	145.3
Average TWL (m)	87.3	87.3	87.3
TWL + losses (m)	90	90	90
Reservoir surface area (km^2)			2

Source: NIRAS 2003; ESCOM.

3.2 IRRIGATED AGRICULTURE

3.2.1 Regional policies for agriculture and irrigation development

New Partnership for Africa's Development (NEPAD)

In October 2001, the New Partnership for Africa's Development (NEPAD) was launched as an Africa-led initiative of the African Union to promote self-sustaining economic development. In Africa, increasing and improving agricultural production is crucial for addressing hunger, poverty, inequality and economic growth. Hence, it was the primary economic sector addressed in the first NEPAD Action Program. In June 2002, the African heads of states and governments approved the Comprehensive Africa Agriculture Development Program (CAADP) as a framework for the restoration of agricultural growth, food security, and rural development in Africa. The program's work falls under four main pillars, three of which focus on investment in interventions: extending the area under sustainable land management and reliable water control systems; increasing market access through improved rural infrastructure and other trade-related interventions; and, increasing food supply and reducing hunger. The CAADP also pays attention to emergencies and disasters requiring food and agricultural responses or safety nets, which, if ignored, can displace people, undermining development achievements. The fourth pillar of the CAADP focuses on agricultural research and technological dissemination and adoption to promote long-term productivity and competitiveness.

Improving agricultural productivity in line with the fourth pillar, will require:

- Linking research and extension systems to producers more efficiently to increase adoption of the most promising technologies and support immediate improvement of African production.
- Providing the technology delivery systems needed to quickly bring innovations to farmers and agribusinesses, particularly through the use of new information and communication technologies (ICTs).
- Renewing the ability of agricultural research systems to adapt new knowledge and technologies—including biotechnology—to Africa's context and increase output and productivity while conserving the environment.
- Promoting mechanisms that reduce the costs and risks of adopting new technologies. For the period 2002 to 2015, a total investment of some $4.6 billion is estimated.

Implementing the CAADP involves collaborative preparation of the National Medium-Term Investment Programs (NMTIPs) and associated bankable investment project profiles (BIPPs). Each of the riparian countries in the ZRB has NMTIPs. Table 3.55. lists agriculture-related projects in the Basin for which the BIPPs have been accounted for in this analysis.

In 2005 the World Bank prepared the most recent Africa Action Plan (AAP) to provide a results-oriented framework to support critical policy and public actions led by African countries to achieve well-defined goals, including the Millennium Development Goals. Slow growth in Sub-Saharan Africa is a result of both lack of investments and low investment efficiency. Since 1995 the fastest-growing economies have benefited from higher investment rates and have generated higher returns on investment. The AAP was intended to support drivers of growth, one of which is productive and sustainable agriculture. In line with the CAADP, the World Bank's strategy for agriculture in Africa is based

Table 3.55. Agriculture projects with Bankable Investment Project Profiles in the Zambezi River Basin

Country	Project name
Malawi	Commercialization of High Value Crop
Mozambique	Small Dam Rehabilitation and Construction Small Scale Irrigation Project II
Namibia	Support to Smallholders Irrigation Schemes
Zambia	Nega Nega Irrigation Scheme
Zimbabwe	Rehabilitation of Smallholder Irrigation Schemes Smallholder Irrigation Development (Mtshabezi and Mazvikadei irrigation schemes)

on two pillars: first, providing loans and advice to countries to help them address domestic barriers to higher productivity; and second, providing analysis and advocacy at the international level to dismantle obstacles to agricultural production and exports. The Bank's strategy calls for increased physical investment in agriculture (especially irrigation), water resources management, rural roads and infrastructure, and research and extension; elimination of policy discrimination against rural goods, and increased service delivery for rural areas in agriculture and other sectors (such as education and health); higher productivity through the use of more sustainable agriculture practices; strengthened natural resource management; and scaled up support to farmers and agribusiness through improved market access and supply chain for development and rural finance.

One of the priorities of the AAP is to "raise agricultural productivity" through:

- Improved agricultural technology (research, extension, and adoption of improved techniques);
- Investment in rural infrastructure through local government and community initiatives;
- Irrigation and water harvesting;
- Sustainable land management;
- Stronger value chains and access to markets, including input markets; and
- Stronger safety nets and greater access to rural finance and risk management.

The Mid-Zambezi Agricultural Water Management for Food Security Program originated from a commitment by the African Development Bank to support the NEPAD initiative and CAAPD. It is one of a several projects in preparation across the SADC region. The proposed program targets Botswana, Zambia, and Zimbabwe and comprises three components: addressing irrigation scheme and related infrastructure development as well as providing support to rain-fed producers.

The World Bank study "Zambezi River Basin, Sustainable Water Resources Development for Irrigated Agriculture" (June 2006) aimed to identify the potential for a major scaling up of economically and environmentally sustainable investment in water resources management for agriculture and rural development in the ZRB.

Southern Africa Development Community, SADC

The first phase of the Regional Strategic Action Plan between 1998 and 2004, created an enabling environment for integrated water resource management (IRWM) in the ZRB. A subsequent strategic action plan was approved in June 2005 by SADC's Integrated Committee of Ministers (ICM) for the period 2005 and 2010. The agricultural sector has been one of the targets of the new plan, which aimed to "develop by 2015 water resources infrastructures needed to double land under irrigation in southern Africa."

The SADC Regional Water Policy from 2007 addresses water resources management in nine thematic areas where the issue of food security is included under water for development and poverty reduction. Food security is further emphasized by the following statements in the policy:

- Member countries will promote the attainment of regional food security rather than national self-sufficiency by developing those areas which have comparative advantage for rain-fed and irrigated agriculture.
- Water resources development for irrigation in commercial agriculture should be planned in coordination with other sectors in the interest of IWRM.
- As a vehicle for promoting reliable food production and enhancing food security, sustainable irrigated agriculture and aquaculture will be promoted in all member countries with suitable water and land resources.
- Member countries will promote improved tillage and rainwater-harvesting techniques to optimize the use of water by rainfed agriculture.
- Member countries will promote affordable and sustainable techniques for small-scale irrigation as a measure to increase production of food and cash crops in rural areas for sustainable livelihoods and poverty reduction.
- Member countries will promote measures for increased water use efficiency in agriculture.
- Water requirements for livestock—including both livestock watering and maintenance of grazing land—shall receive adequate consid-

eration in water resources allocation and management.

The policy stresses that a strategic objective for water for food security is "to attain regional food security through sustainable irrigated agriculture, rainfed agriculture, aquaculture and livestock production, through optimal use of both surface and groundwater with the ultimate goal of poverty reduction." These objectives are reiterated in the goals of the strategies that have developed from the SADC Regional Water Policy:

- Promote agricultural research and its application in the context of water use efficiency, climatic change trends, and temporal climatic variations as the basis for improved productivity.
- Maximize the benefit of water use throughout the region through the principles of comparative advantage and promote sharing of benefits.
- Promote the participation of communities and private sector in the development, improvement, and management of irrigated and rainfed agriculture in small- and medium-scale enterprises
- Promote construction of multipurpose facilities that will benefit irrigation and groundwater recharge to enhance food security.

3.2.2 Overview of agricultural sector

Almost 75 percent of land in the Basin is covered by forests and bush. Cropped land (mostly rain-fed agriculture) covers 13 percent, and grassland covers approximately eight percent of the land area. The rest is barren or used for infrastructure. An estimated 5.2 million hectares is cultivated yearly in the Basin. Together, Zimbabwe, Zambia, and Malawi account for 85 percent of this area (Euroconsult Mott MacDonald 2008b). The agricultural sector[12] is the economic backbone of the ZRB and employs approximately 72 percent of the Basin's labor force. Hence, agriculture is fundamental for the Basin's rural population, who constitue ca 70 percent of the total basin population (table 3.56.) (FAO 2008a). Among the Basin's riparian countries, the agricultural sector contributes an average of 24 percent to country GDP, with significant variation (table 3.57.).

Across the Basin, the varying climatic zones, historical and agricultural developments, population densities, and poverty levels results in different types of farming:

- Traditional farming largely for home consumption and trade of any surplus, either for cash or for services (such as labor).

Table 3.56. Rural population active in agriculture in Zambezi riparian countries

Country	Population	Rural population (no.)	Rural population (%)	Population in active employment (no.)	Population in active employment (%)	Active population in agriculture (no.)	Active population in agriculture (%)
Angola	15,941,000	10,008,000	63%	7,403,000	46%	5,218,000	70%
Botswana	1,765,000	838,000	47%	817,000	46%	354,000	43%
Namibia	12,884,000	10,673,000	83%	6,068,000	47%	4,903,000	81%
Malawi	19,792,000	12,281,000	62%	10,312,000	52%	8,250,000	80%
Mozambique	2,031,000	1,351,000	67%	832,000	41%	311,000	37%
Tanzania	38,329,000	23,956,000	63%	20,224,000	53%	15,802,000	78%
Zambia	11,668,000	7,409,000	63%	4,968,000	43%	3,293,000	66%
Zimbabwe	13,010,000	8,343,000	64%	6,180,000	48%	3,708,000	60%
Zambezi River Basin	**29,968,600**	**21,012,509**	**70%**	**13,992,821**	**47%**	**10,011,529**	**72%**

Source: FAO 2008a, values as of 2005.

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[12] Agriculture includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production.

Table 3.57. Zambezi River Basin's agricultural GDP ($ billion)

Country	National GDP ($ bn)	Agriculture GDP ($ bn)	Agriculture GDP (%)	GDP in ZRB ($ bn)	GDP agricultural sector in ZRB ($ bn)
Angola	58.55	6	10%	1.95	0.20
Botswana	11.78	0	0%	0.11	0.00
Namibia	3.55	1	28%	2.83	0.96
Malawi	7.75	2	26%	1.02	0.29
Mozambique	6.74	1	15%	0.37	0.04
Tanzania	16.18	7	43%	0.52	0.24
Zambia	11.36	2	18%	7.37	1.62
Zimbabwe	—	—	—	—	—
Zambezi River Basin	**—**	**—**	**24%**	**14**	**3**

Source: World Bank 2008a, values for 2007. Estimates for national parts of the basin come from population ratios.

- Emerging farming who largely subsist from their own productivity but whose farming activities produce a marketable surplus of staple and/or industrial or horticultural crops.
- Commercial farming who do not rely upon their own production for subsistence and instead produce most or all of their crops for sale.

In most cases, the irrigation method applied will mirror the type of farming, i.e. traditional, emerging, and commercial irrigation. Within the traditional and the emerging irrigation sector, many farmers are classified as "outgrowers". These farmers typically follow the nucleus estate model, i.e. growers are located around a commercial scheme and may be supported by management of an estate for cultivation, planting material, inputs, and transport and in turn exclusively provide their harvested produce.

The Integrated Water Resources Management Strategy and Implementation Plan for the Zambezi River Basin (Euroconsult Mott MacDonald 2008b) states that agricultural development is key to poverty alleviation and economic growth. This is reiterated in the priorities of the riparian countries' national development plans and strategic goals of development partners and donors (table 3.58.).

There is no single database that contains complete and accurate data concerning agriculture and irrigation in the ZRB. Most of the figures used in recent studies concerning water resources management in the Basin are drawn from the 1998 ZACPRO sector studies (Denconsult 1998c), which also compiled older data and, in most of the cases, national data.

Various sources were used to calculate the figure for the Basin's current irrigation area used in this study. Rather than reusing general figures that appear in water resources management studies, the analysis has sought the most accurate data possible because:

- Irrigation is by far the main water use in the ZRB.[13] The accuracy of the data used will determine the quality of the water resources management model.
- The irrigation sector in the ZRB has recently experienced important changes, including the loss of effective irrigation areas in Zimbabwe and the development of commercial irrigation for sugarcane production in the Kafue River subbasin.
- The main input for the irrigation component of the water resources management model is

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[13] If the evaporation of the reservoirs is not considered to be an abstraction use.

Table 3.58. National and regional policy documents for agriculture and irrigation development

Angola	Review of Agricultural Sector and Food Security Strategy and Investment Priority Setting (July 2004) Towards a Strategy for Agricultural Development in Angola—Issues and Options (March 2005) Plano Director National de Irrigação—Plano Irriga (under preparation)
Botswana	National Master Plan for Arable Agriculture and Dairy Development (2002) Revised National Policy for Rural Development (2002) National Strategy for Poverty Reduction (2002)
Malawi	Agricultural and Livestock Development Strategy and Action Plan (1995) National Irrigation Policy and Development Strategy (June 2000) Strategic Plan from July 2006 to July 2010 (July 2006)
Mozambique	Politicá Agrária e Estratégias de Implementação (1996–97) Plano de Acção para a Redução de Pobreza Absoluta II (PARPA II 2006–09) Visão do Sector Agrário en Moçambique Promoção de Desenvolvimento Agrário II (ProAgri II, 2005–09) National Policy for Irrigation (under preparation)
Namibia	National Agricultural Policy (1995) Review of the National Agricultural Policy of 1995 (2003) National Development Plan 2 (NDP2 for 2001–06) Vision 2030
Tanzania	Rural Development Strategy (2002) Agricultural Sector Development Strategy (2001) National Irrigation Master Plan (2002) National Irrigation Policy (2007) National Water Development Strategy for 2006–15
Zambia	Agricultural Commercialization Program (2001) Vision 2030 National Agriculture Policy (2005) National Irrigation Plan (2006) Firth National Development Plan for 2006–10
Zimbabwe	Zimbabwe's Agriculture Policy Framework 1995–2010 (1996) Land Reform and Resettlement Reform (2000) Ministry of Water Resources and Infrastructural Development "Five Year Development Plan (July 2007)" Ministry of Water Resources and Infrastructural Development "Ten Year Development Plan (July 2007)"
World Bank	Africa Action Plan (AAP)
NEPAD	Comprehensive Africa Agriculture Development Program (CAADP)
SADC	Regional Water Policy (2006) Regional Water Strategy (2007)

Source: This study, 2010.

the future potential irrigation water requirements and abstractions. In the short-term, only existing projects will be considered. For most irrigation projects, however, neither feasibility nor prefeasibility studies are available. When estimating the characteristics of those projects involved making a number of assumptions, based on the current irrigation schemes in the identified projects' areas.

3.2.3 Cultivated area within the Zambezi River Basin

Most of the cultivated land of Malawi, Zambia, and Zimbabwe account for 85 percent of the total of the approximately 5.2 million hectares of cultivated land in the region (table 3.59.).

In the analysis below, equipped area refers to the command area, or irrigable area. The irrigated

Table 3.59. Cultivated area in the Zambezi River Basin (hectares)

Country	Hectares
Angola	92,000
Botswana	1,000
Malawi	1,903,000
Mozambique	421,000
Namibia	15,000
Tanzania	251,000
Zambia	1,154,000
Zimbabwe	1,368,000
Zambezi River Basin	**5,205,000**

Source: World Bank 2006b.

cultivated area is that which is cropped. An equipped area can potentially be used twice a year, which corresponds to an intensity of two or 200 percent. For example, one hectare of irrigated wheat in the dry season could be irrigated with complementary irrigation for one hectare of maize in the wet season.

Tables 3.60. and 3.61. provide a breakdown of irrigation areas in the ZRB by subbasin and by country, respectively. Only 183,000 hectares (3.5 percent) in the ZRB have been identified as equipped areas. At the same time, irrigated areas produce higher yields than those areas without irrigation. For example, irrigated cereals production (around 300,000 tons) accounts for around 10 percent of the total cereal production. Irrigated perennial crops account for 56 percent of the total equipped area, equivalent to 102,000 hectares. Sugarcane accounts for 76 percent of irrigated perennial crops.

Large parts of the total equipped area can have two productive seasons because of favorable climatic conditions: summer (or wet season, from November–December to March–April) and winter (or dry season, April–May to September–October). In the summer season, heavy rainfall accounts for the majority of the water supply to crops, so irrigation needs are marginal. In winter, however, irrigation provides the majority of water supply for crop production. Excluding perennial crops, the irrigation areas have a mean cropping intensity of 195 percent because of two cropping seasons.

Winter wheat accounts for 50 percent of the irrigated winter crop areas. Finally, some of the irrigation areas are associated with storage facilities. This is the case for the irrigation schemes of the Kafue Flats where storage provided by the Itezhi Tezhi reservoir, for irrigation downstream of Lake Malawi/Niassa/Nyasa, and the man-made Lake Kariba and Lake Cahora Bassa, and for the irrigation schemes that withdraw waters from the Zimbabwean tributaries where storage is provided by small reservoirs.

3.2.4 Water abstractions for existing irrigation schemes

The annual water abstractions for irrigation schemes in the ZRB total of 3,234 million m^3, or 2.5 percent of the estimated[14] 130 billion m^3 per year available runoff (Euroconsult Mott MacDonald 2007). Zambia, Zimbabwe, and Malawi respectively account for 15 percent, 27 percent, and 46 percent of water abstrac-

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[14] In this rapid assessment, the irrigation abstractions needs are estimated to be around 1.5 million m^3. This value was probably underestimated because it was calculated using data from the 1990s (i.e., much less perennial crops irrigation areas taken into account).

Table 3.60. Irrigation areas in the Zambezi River Basin (hectares/subbasin)

Subbasin	Irrigated (ha)	Equipped (ha)	Dry season (ha)	Wet season (ha)	Perennial (ha)
Kabompo (13)	595	350	245	245	105
Upper Zambezi (12)	3,250	2,500	1,750	750	750
Lungúe Bungo (11)	1,250	1,000	750	250	250
Luanginga (10)	1,000	750	500	250	250
Barotse (9)	340	200	140	140	60
Cuando/Chobe (8)	765	620	495	145	125
Kafue (7)	46,528	40,158	6,370	6,370	33,788
Kariba (6)	44,531	28,186	16,325	16,345	11,861
Luangwa (5)	17,794	10,100	7,935	7,694	2,165
Mupata (4)	21,790	14,200	7,589	7,590	6,611
Shire River - Lake Malawi/ Niassa/Nyasa (3)	60,960	42,416	18,606	18,544	23,810
Tete (2)	52,572	35,159	19,411	17,413	15,748
Zambezi Delta (1)	7,664	6,998	666	666	6,332
Total	**259,039**	**182,637**	**80,782**	**76,402**	**101,855**

Table 3.61. Irrigation areas in the Zambezi River Basin (hectares/country)

Country	Irrigated (ha)	Equipped (ha)	Dry season (ha)	Wet season (ha)	Perennial (ha)
Angola	6,125	4,750	3,375	1,375	1,375
Botswana	0	0	0	0	0
Malawi	37,820	30,816	7,066	7,004	23,750
Mozambique	8,436	7,413	1,023	1,023	6,390
Namibia	140	120	120	20	0
Tanzania	23,140	11,600	11,540	11,540	60
Zambia	74,661	56,452	18,448	18,209	38,004
Zimbabwe	108,717	71,486	39,210	37,231	32,276
Total	**259,039**	**182,637**	**80,782**	**76,402**	**101,855**

tion (table 3.64.). The majority of water consumption for irrigation takes place in the subbasins of Tete, Shire River and Lake Malawi/Niassa/Nyasa, Mupata, Kariba and Kafue. Those areas also have notably large commercial agriculture and therefore have the greatest potential for an increase in irrigation in the future. The winter season is characterized by the highest needs for water abstraction.

3.2.5 Recession irrigation

In the Zambezi River Basin, recession or natural submersion irrigation[15] accounts for a significant part of irrigation, more than 100,000 hectares (table 3.66.). This is particularly true for the wetlands of the ZRB. They are extensive, particularly in the upper reaches, and provide many rural people with

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[15] As the floodwater recedes from the river banks, fertile land can be farmed.

Table 3.62. Irrigated crops in the Zambezi River Basin by subbasin (hectares)

	Dry season crops							Perennial crops						Wet season crops						TOTAL	TOTAL
Subbasin	**Winter wheat**	**Winter rice**	**Winter maize**	**Veg-etables**	**Beans**	**Winter cotton**	**Other**	**Sugar-cane**	**Tea**	**Coffee**	**Citrus**	**Banana**	**Pasture**	**Maize**	**Soy-beans**	**Sor-ghum**	**Cotton**	**Tobacco**	**Rice**	**Irrigated**	**Equipped**
Kabompo (13)	136	0	0	64	0	0	45	0	0	0	23	0	82	88	0	0	0	48	0	595	350
Upper Zambezi (12)	0	1,000	0	750	0	0	0	0	0	0	750	0	0	0	0	0	0	0	0	3,250	2,500
Lungúe Bungo (11)	0	500	0	250	0	0	0	0	0	0	250	0	0	0	0	0	0	0	0	1,250	1,000
Luanginga (10)	0	250	0	250	0	0	0	0	0	0	250	0	0	0	0	0	0	0	0	1,000	750
Barotse (9)	78	0	0	36	0	0	26	0	0	0	13	0	47	51	0	0	0	27	0	340	200
Cuando/Chobe (8)	0	350	0	145	0	0	0	0	0	0	125	0	0	0	0	0	0	0	0	765	620
Kafue (7)	6,370	0	0	0	0	0	0	33,068	0	596	0	124	0	0	5,868	0	0	502	0	46,528	40,158
Kariba (6)	10,703	0	0	2,294	0	500	2,828	6,434	757	1,137	1,023	25	2,485	3,250	2,363	0	3,590	2,020	0	44,531	28,186
Luangwa (5)	4,689	0	0	2,525	241	0	480	0	0	0	1,563	0	602	3,048	0	0	0	1,641	0	17,794	10,100
Mupata (4)	5,240	0	0	1,072	0	0	1,277	3,618	426	1,069	646	0	852	1,311	1,329	0	1,737	864	0	21,790	14,200
Shire River and Lake Malawi/Niassa/Nyasa (3)	13,450	0	95	2,443	62	0	3,361	9,523	1,121	1,682	1,179	0	2,243	3,308	1,526	13	4,610	2,152	0	52,572	35,159
Tete (2)	0	13,700	3,579	1,327	0	0	0	19,750	4,060	0	0	0	0	1,790	645	286	859	0	13,637	60,960	42,416
Zambezi Delta (1)	0	0	0	666	0	0	0	5,666	0	0	666	0	0	0	0	0	0	0	0	7,664	6,998
Total	**40,666**	**15,800**	**3,674**	**11,822**	**303**	**500**	**8,017**	**78,059**	**6,364**	**4,484**	**6,488**	**149**	**6,311**	**12,846**	**11,731**	**299**	**10,796**	**7,254**	**13,637**	**259,039**	**182,637**
% of winter crops	50%	20%	5%	15%	0%	1%	10%														
% of summer crops				15%			10%							17%	15%	0%	14%	9%	18%		
% of perennial crops								77%	6%	4%	6%	0%	6%								

Note: One hectares of vegetables appears in the "dry season" columns" even if two seasons of vegetables may be cultivated.

Table 3.63. Irrigated crops in the Zambezi River Basin by country (hectares)

	Dry season crops							Perennial crops						Wet season crops						TOTAL	TOTAL
Country	**Winter Wheat**	**Winter Rice**	**Winter Maize**	**Veg-etables**	**Beans**	**Winter Cotton**	**Other**	**Sugar-cane**	**Tea**	**Coffee**	**Citrus**	**Banana**	**Pasture**	**Maize**	**Soy-beans**	**Sor-ghum**	**Cotton**	**Tobacco**	**Rice**	**Irrigated**	**Equipped**
Angola	0	2,000	0	1,375	0	0	0	0	0	0	1,375	0	0	0	0	0	0	0	0	6,125	4,750
Botswana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malawi	0	3,891	2,425	750	0	0	0	19,750	4,000	0	0	0	0	1,213	437	194	582	0	3,828	37,820	30,816
Mozambique	0	0	95	866	62	0	0	5,666	0	0	724	0	0	79	28	13	37	0	0	8,436	7,413
Namibia	0	100	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	140	120
Tanzania	0	9,809	1,154	577	0	0	0	0	60	0	0	0	0	577	208	92	277	0	9,809	23,140	11,600
Zambia	13,018	0	0	3,599	241	500	1,090	33,068	0	1,026	2,085	124	1,701	4,323	5,868	0	500	2,829	0	74,661	56,452
Zimbabwe	27,648	0	0	4,635	0	0	6,927	19,575	2,304	3,458	2,304	25	4,610	6,654	5,190	0	9,400	4,425	0	108,717	71,486
Total	**40,666**	**15,800**	**3,674**	**11,822**	**303**	**500**	**8,017**	**78,059**	**6,364**	**4,484**	**6,488**	**149**	**6,311**	**12,846**	**11,731**	**299**	**10,796**	**7,254**	**13,637**	**259,039**	**182,637**

Source: MSIOA 2009.

Note: One hectare of vegetables appears in the "dry season" columns" even if two seasons of vegetables may be cultivated.

Table 3.64. Annual water abstraction requirements for irrigation in the Zambezi River Basin by subbasin (1,000 m^3)

Subbasin	Water abstractions	Percent
Kabompo (13)	4,817	0%
Upper Zambezi (12)	37,623	1%
Lungúe Bungo (11)	15,674	0%
Luanginga (10)	14,203	0%
Barotse (9)	3,491	0%
Cuando/Chobe (8)	10,139	0%
Kafue (7)	626,021	19%
Kariba (6)	649,154	20%
Luangwa (5)	120,498	4%
Mupata (4)	308,562	10%
Shire River and Lake Malawi/Niassa/Nyasa (3)	648,649	20%
Tete (2)	669,032	21%
Zambezi Delta (1)	126,973	4%
Total	**3,234,836**	**100%**

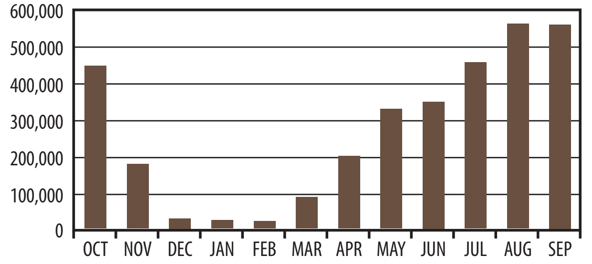
Table 3.65. Annual water abstraction requirements for irrigation in the Zambezi River Basin by country (1,000 m^3)

Country	Water abstractions	Percentage of total
Angola	75,677	2%
Botswana	0	0%
Malawi	494,583	15%
Mozambique	133,676	4%
Namibia	1,961	0%
Tanzania	154,065	5%
Zambia	879,254	27%
Zimbabwe	1,495,619	46%
Total	**3,234,836**	**100%**

Table 3.66. Main recession irrigation areas in the Zambezi River Basin (hectares)

Name of the floodplain	Subbasin	River	Country	Floodplain area (ha)	Recession area (ha)
Barotse Floodplain	9	Zambezi	Zambia	900,000	28,000
Caprivi-Chobe Lake Liambezi floodplain	8	Cuando/Chobe	Namibia, Botswana	220,000	9,000
Kaufe Flats	7	Kafue	Zambia	650,000	13,000
Luangwa Valley Floodplain	5	Luangwa	Zambia	1,080,000	17,000
Lower Shire Floodplain	3	Shire	Malawi	1,510,000	21,000
Zambezi Delta Floodplain	1	Zambezi	Mozambique	1,940,000	25,000
Total				**6,300,000**	**113,000**

Figure 3.1. Monthly water abstraction requirements in the Zambezi River Basin (m^3/s)



staple crops, fish, construction materials, and more. Yet little is known about the biodiversity of those wetlands and the amount of natural resources available. Even estimates of average size are often only very roughly approximated.

3.2.6 Estimated equipped area – ZACPRO 6 sector study and MSIOA

Despite the limited data available, ZACPRO 6 carried out a systematic analysis of land use in the ZRB in the mid-1990s (Denconsult 1998b). Their estimates indicated that in 1995 the equipped irrigation area was approximately 171,551 hectares (about 3.6 percent of cultivated area). Based on the estimates done as part of the MSIOA, it appears that irrigation areas have increased slightly in the riparian countries apart from a recent decrease in Zimbabwe (table 3.67.).

3.2.7 Agricultural production trends

Agriculture is the economic backbone of the region and continues be a vital part of each country's economy. Moreover, agriculture contributes significantly to direct exports. In addition, the agro-processing and manufacturing industries depend heavily on farming input and contribute significantly to exports. Though the manufacturing and service sectors are comparatively weak in the Basin, expanding the production of agricultural commodities for processing and manufacturing industries can have significant multiplier effect. This stimulates growth in other services, economic growth and if effective, desired poverty reduction.[16] Agriculture accounts for a significant part of GDP growth in many countries, for example, 50 percent in Zimbabwe, 40 percent in Tanzania, and 20 percent in Mozambique.

The increase in crop production in the ZRB demonstrates the strategic importance of agricultural development. Cereal production has increased during the past decade in all riparian countries, except for Zimbabwe (figure 3.2.). In the early 1990s, for example, Zambia produced about 30,000 tons of wheat/year and imported about 120,000 tons. Current production is about 160,000 tons per year, compared with 40,000 tons for imports. Most of Zambia's wheat is grown with irrigation using center-pivots techniques. The main drivers for the increase in production have been attractive market prices and electrification of farming blocks.

Table 3.67. Comparison of equipped irrigation areas (MSIOA and ZACPRO 1998 studies)

Equipped area per country (ha)	MSIOA	ZACPRO 6 Sector study (ha)	Difference
Angola	4,750	975	3,775
Botswana	0	661	–661
Malawi	30,816	36,500	–5,684
Mozambique	7,413	4,630	2,783
Namibia	120	820	–700
Tanzania	11,600	150	11,450
Zambia	56,452	42,335	14,117
Zimbabwe	71,486	85,550	–14,064
Total	**182,637**	**171,621**	**11,016**

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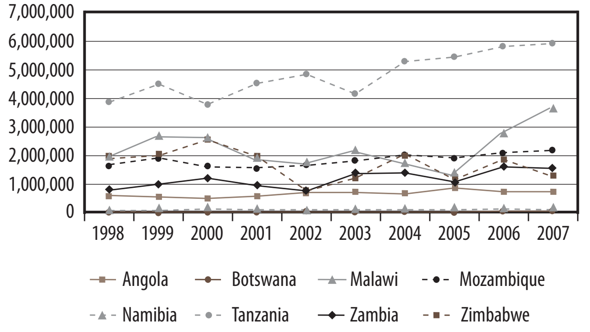
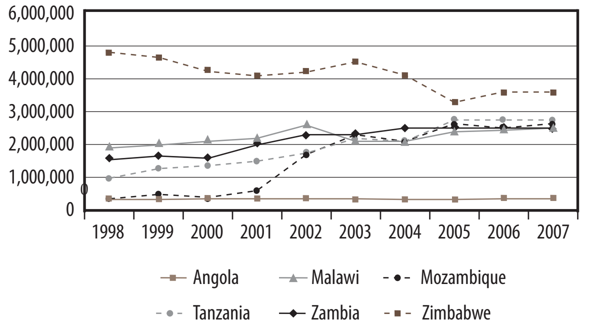
[16] As stated in World Bank 2006d and the figures are 2000–2004 data from World Bank 2008e.

Figure 3.2. Production of cereals by country (tons)



Source: FAO 2008b.

Figure 3.3. Production of sugar cane by country (tons)



Source: FAO 2008b.

Sugarcane production has also increased (figure 3.3.). Zambia's main producer of sugar, the Zambia Sugar Company, has driven the country's sugar production from 22,000 tons in 1962 to 250,000 tons in 2006, all of which is irrigated entirely. Zambia exports over half of total production: 80,000 tons to the Democratic Republic of Congo, 30,000 tons to countries in the Great Lakes region, and 20,000 tons to the Southern Africa Customs Union.[17]

3.2.8 Water availability and regulation

Annual water abstractions for irrigation schemes represent only 2.5 percent of the estimated available runoff over the ZRB (Source: MSIOA [HEC3 simulation without large artificial regulation over the ZRB], 2010). There is therefore room for irrigation extension, given the development of appropriate regulation. Several levels of irrigation development are modeled in the MSIOA Study. Some stretches of the Zambezi River and its tributaries are already precisely regulated, including: the lower Zambezi (downstream Kariba and Cahora Bassa reservoirs); the Shire River (downstream Lake Malawi/Niassa/Nyasa); the Kafue River (downstream Itezhi Tezhi Reservoir); and the Zimbabwean tributaries (with numerous small regulation reservoirs for irrigation).

Southern Africa is known for recurrent drought conditions that span the entire region causing famine and mortality. The most notorious droughts in recent history hit the region in 1991–92 and 1994–95. More recent droughts occurred in Zambia in 2002 and in Tanzania in 2006. These droughts affected water supplies in both rural and urban areas (urban centers were subjected to severe water rationing) and reduced crop harvests. This is especially true for rainfed agricultural areas. Sensitivity to the detrimental impacts of droughts can be significantly reduced by developing and rehabilitating appropriate irrigation systems, often in combination with regulation reservoirs.

Most parts of the Zambezi River Basin rely heavily on food imports. Based on the MSIOA assessment, each subbasin, apart from Mupata, would remain cereal deficient if there was no access to imports, even if all identified irrigation projects were implemented (table 3.68.). The overall food security is under control in the Basin, but remains a problem certain geographic areas. In Zimbabwe, for example, food insecurity threatens certain parts of the country; and in Malawi, more than 500,000 people are at risk of food insecurity (USAID 2008).

3.2.9 Population density in irrigated areas

The per capita ratio of arable and permanently cropped land area is low in the in ZRB's rural areas. Most rural households average only one to two per hectares, with an average of 0.5 hectares per capita among those active in agriculture. Only in Angola, Botswana, Namibia and Zambia is the per capita ratio above 0.5 hectares.

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[17] Stephens T., 2008.

Table 3.68. Cereal import requirement (1,000 tons)

	Angola	Botswana	Malawi	Mozambique	Namibia	Tanzania	Zambia	Zimbabwe	Total	%
Kabompo (13)	1	0	0	0	0	0	30	0	31	2.00%
Upper Zambezi (12)	25	0	0	0	0	0	–8	0	17	1.10%
Lungúe Bungo (11)	13	0	0	0	0	0	–9	0	4	0.30%
Luanginga (10)	8	0	0	0	0	0	–4	0	4	0.30%
Barotse (9)	1	0	0	0	7	0	–2	0	6	0.40%
Cuando/Chobe (8)	16	1	0	0	1	0	8	0	26	1.70%
Kafue (7)	0	0	0	0	0	0	347	0	347	22.30%
Kariba (6)	0	–51	0	0	–11	0	6	320	264	17.00%
Luangwa (5)	0	0	6	1	0	0	19	0	26	1.70%
Mupata (4)	0	0	0	0	0	0	–10	–62	–72	–4.60%
Shire River and Lake Malawi/ Niassa/Nyasa (3)	0	0	27	140	0	0	25	–60	132	8.50%
Tete (2)	0	0	540	81	0	138	1	0	760	48.90%
Zambezi Delta (1)	0	0	0	8	0	0	0	0	8	0.50%
Total	**64**	**–50**	**573**	**230**	**–3**	**138**	**403**	**198**	**1553**	**100.00%**
%	4.10%	–3.20%	36.90%	14.80%	–0.20%	8.90%	25.90%	12.70%	100.00%	

Note: The figures (Denconsult 1998b) need updating, especially in Zambia and Malawi due to recent agricultural growth (through primarily maize and wheat).

The per capita ratio of equipped irrigated land is extremely low—less than 0.02 hectares/capita among those active in agriculture. Irrigation is therefore often confined to the equivalent of a household garden, except near wetlands or seasonally flooded wetlands. Low irrigation development leads to low agricultural yields and increases the pressure on the existing wetlands (especially dambos), which are overexploited and subject to conflicts. The absence of adequate secure land–tenure arrangements inhibits long-term investments for commercial farming, undermined further by lack of access to credit as banks prefer to lend money against collateral such as title deeds.

National agricultural yields are very low across the Basin, even if the irrigation areas are taken into account. The average cereal yield is estimated to be one ton per hectare compared to the irrigation standard of around five tons per hectare (FAO, table 3.69.).

Table 3.69. Maize and paddy rice yields by country in the Zambezi River Basin *(tons/hectare)*

Country	Maize	Rice, paddy
Angola	0.5	0.7
Botswana	0.2	0.0
Malawi	2.0	1.7
Mozambique	1.0	1.0
Namibia	2.2	0.0
Tanzania	1.1	1.9
Zambia	1.6	1.3
Zimbabwe	0.7	2.4

Source: FAO 2008b, values from 2007.

The low per capita levels of cultivated land and the associated low yields is directly related to food insecurity and the reliance on food imports throughout the ZRB.

3.2.10 Commercially viable agriculture – the case of sugar

The cheapest country for producing sugar is Brazil. This is primarily due to favorable economies of scale, low input costs and producing being entirely rainfed. After Brazil follows Zimbabwe, Malawi, Swaziland, Sudan, and Zambia in terms of cost. Nevertheless, Zambia's sugar production is about 50 percent more expensive than Brazil's (table 3.70., Kafue).

3.2.11 High irrigation potential

The average yield of cereal in the ZRB is around one ton per hectare, compared to a potential irrigated yield of five to eight tons per hectare. There is tremendous potential for increased agricultural production given the availability of water for timely

Table 3.70. Irrigation – strengths and challenges

Subbasin	Strengths	Challenges
Kabompo (13)	Water and land availability.	Water access: irrigation is very underdeveloped. Very low crop yields. Geographically isolated.
Upper Zambezi (12)	Water and land availability.	Water access: irrigation is very underdeveloped. Very low crop yields. Geographically isolated.
Lungúe Bungo 11)	Water and land availability.	Water access: irrigation is very underdeveloped. Very low crop yields. Geographically isolated.
Luanginga (10)	Water and land availability.	Water access: irrigation is very underdeveloped. Very low crop yields. Geographically isolated.
Barotse (9)	Recession irrigation possible in the Barotse Floodplain.	Irrigation is very under-developed. Geographically isolated.
Cuando/Chobe (8)	Recession irrigation possible in the Linyati Floodplain.	Irrigation is very under-developed. Very low crop yields. Geographically isolated.
Kafue (7)	Recession irrigation possible in the Kafue Flats. Water regulation from Itezhi Tezhi reservoir. Availability of know-how, good irrigation performance, and infrastructure, especially for sugarcane schemes. The equipped irrigation area is relatively important in this subbasin and has increased significantly during the last 10 years. Large sugarcane exporter.	Cash crop production lacks competitiveness (for example, in the case of sugar production compared to Brazil). Highly dependent on cereal imports. Numerous electrical shortages and diminishing availability of irrigable land.

Continued on next page

Table 3.70. Irrigation – strengths and challenges *(continued)*

Subbasin	Strengths	Challenges
Kariba (6)	Increased agricultural production in Zambia (irrigation development) Availability of know-how, good irrigation performance, and infrastructure, especially for Zimbabwe tributaries.	Agricultural production in Zimbabwe has decreased during the last 10 years, and the country faces food insecurity. The irrigation area in Zimbabwe has decreased during the last 10 years because of lack of maintenance. High sensitivity to droughts in the southern parts of the Zambezi River Basin. Low level of cultivated/irrigated land per person.
Luangwa (5)	Recession irrigation possible in the Luangwa valley.	Irrigation would require regulation.
Mupata (4)	Water regulation from Kariba reservoir. Availability of know-how, good irrigation performance, and infrastructure, especially for Zimbabwe tributaries. Water regulation from small dams in Zimbabwe. Self sufficient in cereal production.	Agricultural production in Zimbabwe has decreased during the last 10 years, and the country faces food insecurity. The irrigation area in Zimbabwe has decreased during the last 10 years because of lack of maintenance.
Shire River and Lake Malawi/ Niassa/Nyasa (3)	Recession irrigation possible in the Shire River Floodplain. Water regulation from Lake Malawi/Niassa/ Nyasa. More than 80% of the active population is engaged in agriculture. Cereal production has more than doubled over the last three years. The summer season crops do not generally require supplementary irrigation because of the natural rain irrigation, and the winter crop supplementary irrigation requirements are the lowest in the basin. Higher yields for rainfed agriculture than elsewhere in the Zambezi River Basin.	Very low level of cultivated/irrigated land per capita. High sensitivity to flood in the Shire River valley.
Tete (2)	Water regulation from Kariba and Cahora Bassa reservoirs. Availability of know-how, good irrigation performance, and infrastructure, especially for Zimbabwe tributaries. Around 80% of the active population is active in agriculture.	Agricultural production in Zimbabwe has decreased during the last 10 years and the country is facing food insecurity. The irrigation area in Zimbabwe has decreased during the last 10 years because of lack of maintenance. High sensitivity to droughts in the southern parts of the Zambezi River Basin. Low level of cultivated/irrigated land per person. High sensitivity to flood in Mozambique (notably for the floodplain at the confluence of the Zambezi and the Shire rivers).
Zambezi Delta (1)	Recession irrigation possible in the Zambezi Delta floodplain. Around 80% of the active population is engaged in agriculture. Regulation of Cahora Bassa Dam permits development of irrigated agriculture in dry season.	Frequency and intensity of floods have reduced drastically compared to pre-regulation conditions from the Cahora Bassa reservoir. Low level of cultivated/irrigated land per capita.

irrigation and access to modern control inputs for farmers. Improved irrigation practices will also increase productivity of summer crops such as summer maize and soybean during the wet season. Furthermore, irrigation will allow perennial crops such as sugarcane, and winter crops such as winter wheat, to be cultivated. The profitability of irrigated crops and the availability of necessary input enhance the region's high irrigation potential.

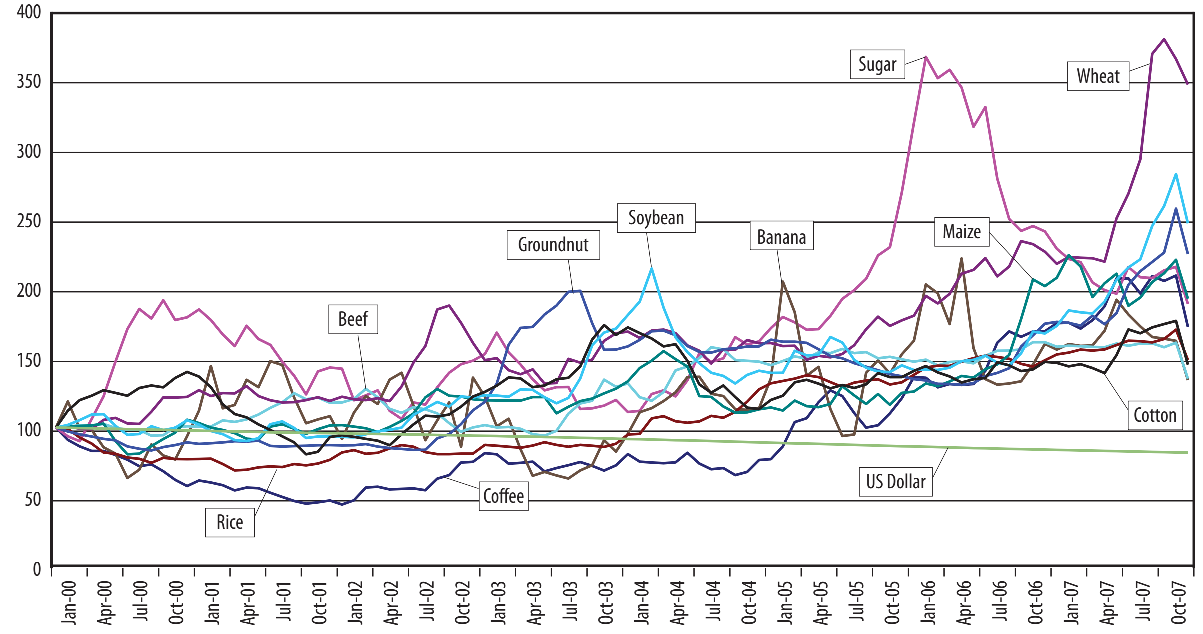
Commodity prices

In recent years, agricultural commodity prices have increased to unforeseen levels (figure 3.4.). The increase was spurred by demand for biofuels (such as the replacement of staple crops with biodiesel and the use of staple crops such as maize as a source of ethanol) and increased demand for food from fast growing economies in Asia. The high agricultural prices may stabilize at a high level and combined with reduced food reserves, regional food security in the ZRB is undermined and increases the need for higher production from improved and expanded use of water for irrigation.

Green schemes – commercial farmers plus outgrowers

The objective of green schemes is to link new irrigation farmers with a commercial enterprise to encourage diversified production of high value crops. They have already developed in some areas of the ZRB (for example, sugar production in the Kafue subbasin). The commercial operator ensures quality, supplies market links, and provides substantial private capital to co-finance national development objectives. In general, half of the scheme areas engage landless farmers on three hectare plots on the basis of bankable leaseholds (settlers have to repay the in-field equipment) and the other half of the scheme area is leased to a commercial operator who shall develop a farm irrigation system, provide technical advice during the planting season, and support the smallholders in marketing their crops. The operator must also finance the necessary buildings, such as storage and offices. The leasehold duration and financial contribution of the commercial operator and small-scale farmers are reviewed regularly and the experience is applied to new projects under construction.

Figure 3.4. Price volatility of select agricultural commodities (2000–07)



Source: Euroconsult Mott MacDonald 2008b, based on World Bank Commodity Prices and inflation data.

Market prospects for irrigation growth

- Wakefield and Riddell (2005) analyzed the market prospects of the main crop groups in Sub-Saharan and southern Africa. They concluded that among cereal staple crops, rice has the largest potential to drive irrigation growth, particularly with the large market demand in South Africa. Wheat demand is also forecasted to increase substantially and when combined with other crops could drive irrigation development.
- Any growth in sugar production that depends on irrigation will rely on private investment. Private investors have created niche markets for horticulture and fruit crops through providing possible out-grower or contract farming opportunities. But demand for most horticulture and fruit crops will continue to be driven by domestic demand and cross-border trade opportunities. While they will continue to have an important place in irrigated cropping patterns, they are not expected to drive irrigation growth at rates beyond population and economic growth.
- Other than fibers, products such as coffee, tea, and tobacco are do not have significant impact on irrigation growth. Yet the potential for increased exports of commodities such as cotton can be important driving force for irrigation development.
- Livestock output generally has a higher farm-gate value than cereal grains and is projected to grow more rapidly than crop output. Even though livestock production currently depends mainly on grazing, high growth in livestock output could be a driver for increased production of irrigated feed crops, such as feed barley, maize, alfalfa, and other green fodder crops.
- There is increasing interest in growing biofuels in the Zambezi River Basin among both farmers and governments. The crops that are being considered include maize, sugar, cassava, sunflower, groundnuts, sweet sorghum, oil palm, and jatropha. In addition, the development of biofuels could promote import substitution.

Table 3.71 outlines some of the challenges to irrigation by subbasin.

3.2.12 Identified irrigation projects

Many irrigation projects are underway in the ZRB (tables 3.72. and 3.73.). As part of the MSIOA Study, irrigation projects were listed, compiled and analyzed from bibliographical sources and from meetings with stakeholders in the riparian countries.

The list included approximately 100 projects and/or programs[18] which are described in more detail in volume 4. Combined, these 100 projects represent a potential increase of more than 336,000 additional hectares of equipped area. The total equipped area will therefore reach around 520,000 hectares.

The additional irrigated area (that is, the sum of winter, summer, and perennial irrigated area) is 514,000 hectares. That figure includes 140,000 hectares of additional irrigated perennial crops or around 42 percent of the total equipped area.

Without the perennial crops, the projected irrigation areas have a mean cropping intensity of 195 percent. Winter wheat represents 38 percent of the projected irrigated winter crop areas.

3.3 WETLANDS

3.3.1 Direct and indirect use

Direct and indirect value includes the consumptive uses of riverine natural resources, such as fish and trees, by rural communities with strong livelihood links with the river. Commercial uses of the ecosystem services, other than non-consumptive activities such as tourism, and the benefits of multiplier effects have not been included in the evaluation.

For the Zambezi River Basin, some of the most common direct values reported are:

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[18] One identified program is sometimes an agglomeration of many smaller neighbour identified projects. For instance: "Rehabilitation/optimization of the use of reservoirs in the Luenya subbasin in Zimbabwe" is considered as 1 program whereas it may deal with many different schemes.

Table 3.71. Irrigation sector – challenges

Subbasin	Identified projects (ha)	Challenges
Kabompo (13)	6,300	Potential difficulty for marketing. Need for regulation to develop irrigation with potential impacts on wetlands.
Upper Zambezi (12)	5,000	Potential difficulty for marketing. Need for regulation to develop irrigation with potential impacts on wetlands.
Lungúe Bungo (11)	500	Potential difficulty for marketing. Need for regulation to develop irrigation with potential impacts on wetlands.
Luanginga (10)	5,000	Potential difficulty for marketing. Need for regulation to develop irrigation with potential impacts on wetlands.
Barotse (9)	7,000	Potential difficulty for marketing. Need for regulation to develop irrigation with potential impacts on wetlands. Land tenure issues.
Cuando/Chobe (8)	300	Impacts on wetlands, wildlife and tourism. Land tenure issues.
Kafue (7)	13,600	Potential conflicts with other uses. Shortage of energy to develop irrigation.
Kariba (6)	120,000	Land tenure issues.
Luangwa (5)	6,000	Need for regulation to develop irrigation with potential impacts on wetlands.
Mupata (4)	6,000	
Shire River - Lake Malawi/Niassa/Nyasa (3)	60,000	Need for regulation to develop irrigation with potential impacts on wetlands. Risk of flood.
Tete (2)	30,000	Need for regulation to develop irrigation with potential impacts on wetlands. Potential difficulty for marketing.
Zambezi Delta (1)	77,000	Potential conflicts with other uses. Risk of flood.

Note: see volume 4 for more details about the identified projects.

- Floodplain grazing areas for cattle;
- Floodplain recession agriculture;
- Fish as a nutritional resource;
- Wild animals and birds as nutritional resources;
- Floodplain reeds, papyrus, and grasses;
- Floodplain palm trees and mangroves;
- Wild plants for food, cooking, and medicine; and
- Clay.

River ecosystems provide many regulatory functions and services with far reaching benefits. For example, floodplains provide flood storage and maintain the water supply in dry months; and, the maintenance of soil moisture levels and floodplain vegetation benefits livestock grazing and floodplain agriculture.

The Zambezi River system also provides primary indirect values (not included in the direct-use pathway), such as:

- Flood attenuation and flood control;
- Groundwater recharge and water supply;
- Retention of fine sediments;
- Nutrient cycling;
- Shoreline protection;
- Wildlife habitat, breeding, and nursery grounds;
- Microclimate regulation; and
- Carbon sequestration and storage.

Table 3.72. Identified projects (additional irrigation) areas in the Zambezi River Basin (ha/subbasin)

Subbasin	Irrigated	Increase (%)	Equipped	Increase (%)
Kabompo (13)	10,719	1,802%	6,300	1,800%
Upper Zambezi (12)	5,000	154%	5,000	200%
Lungúe Bungo (11)	625	50%	500	50%
Luanginga (10)	5,000	500%	5,000	667%
Barotse (9)	12,413	3,651%	7,008	3,504%
Cuando/Chobe (8)	450	59%	300	48%
Kafue (7)	20,520	44%	13,610	34%
Kariba (6)	184,388	414%	119,592	424%
Luangwa (5)	11,063	62%	6,130	61%
Mupata (4)	8,566	39%	5,860	41%
Shire River and Lake Malawi/Niassa/Nyasa (3)	101,166	166%	59,511	140%
Tete (2)	55,621	106%	30,336	86%
Zambezi Delta (1)	99,110	1,293%	77,055	1,101%
Total	**514,641**	**199%**	**336,202**	**184%**

Table 3.73. Identified projects (additional irrigation) areas in the Zambezi River Basin (ha/country)

Country	Irrigated	Increase (%)	Equipped	Increase (%)
Angola	10,625	173%	10,500	221%
Botswana	20,300	—	13,800	—
Malawi	78,026	206%	47,911	155%
Mozambique	137,410	1629%	96,205	1298%
Namibia	450	321%	300	250%
Tanzania	23,140	100%	11,600	100%
Zambia	61,259	82%	37,422	66%
Zimbabwe	183,431	169%	118,464	166%
Total	**514,641**	**199%**	**336,202**	**184%**

In addition, the above ecosystem services protect and mitigate physical damages from extreme hyrdoclimatic events. Although these direct and indirect values are recognized, it is very difficult to economically assess their true value in monetary terms. This is especially true for the indirect values of wetlands. Assessing ecosystem services becomes even more complex and undeniably more important when trying to estimate their values for communities or societies whose fortitude depends upon them, in both material and non-material terms.

In rural areas in developing countries, rivers provide food, water, a navigation system for movement and interaction, construction material, firewood, and much more. The full value of a complete river system for all its users has never been comprehensively ascertained. Seeking a much more complete understanding of ecosystem services and their values to subsistence users have, until recently, typically been neglected in water resource management and development plans.

People live along the full length of the network of waterways that make up the Zambezi River system, and millions of people depend on its natural resources at various levels. The geographic corridor where most of the population at risk (PAR) live is yet undefined in the ZRB. In addition, for most of the network length, there is limited research and understanding of the complex nature of the relationships between the Zambezi River's ecosystems and the communities that live with and depend upon its resources.

3.3.2 Types of wetlands in the Zambezi River Basin

Wetlands may be defined as those areas where an excess of water is the dominant factor determining the nature of soil development and the types of animal and plant communities living at the soil surface. By definition, these areas—including riverine floodplains, papyrus swamps, marshes, mangrove swamps, and estuaries—would be significantly altered by a change in their flow and/or inundation regime. In the Zambezi River system, the principal types of wetlands are (table 3.74.):

- Riverine, which includes all floodplains along the river system, such as Barotse, Kafue, and Luangwa;
- Dambos, which are found throughout the basin; and
- Fringe, which are found at Kariba, Cahora Bassa, and Itezhi Tezhi reservoirs.

Given a dearth of information and research of these areas, six significant wetlands along the system that may be affected by future water resources developments are used to provide insights into the nature, use, and value of wetland resources:

- The Barotse Floodplain;
- The Eastern Chobe-Caprivi Floodplain;
- The Kafue Wetlands;
- The Luangwa Wetlands (Lunsemfwa);
- The Lower Shire Wetlands; and
- The Zambezi Delta.

For each of these six areas, major relevant documents have been reviewed to summarize the river's resources, links between resources and river flow and sediment regimes, use of resources by people, and the value of the resources. Turpie and others (1999) is the most detailed document in the above respect, and is quoted extensively for the Barotse, Chobe-Caprivi, Lower Shire and Delta wetland areas with respect to the following aspects:

- concept of value;
- types of economic value of wetlands;

Table 3.74. Major wetlands and subsistence use of the Zambezi River Basin

Wetland	Subsistence use	Conservation status
Kafue Flats	Fishery, grazing, wildlife, limited agriculture	Partly protected
Lukanga	Fishery, grazing, transport	Unprotected
Barotse Floodplain	Fishery, grazing, wildlife, limited agriculture	Partly protected
Liuwa Floodplain	n/a	n/a
Linyanti-Chobe	Fishery, tourism, no subsistence use	Almost all protected
Cuando	n/a	n/a
Elephant Marsh	Fishery, grazing, agriculture	Unprotected
Luangwa	n/a	n/a
Busanga	Unexploited wildlife refuge	Completely protected
Luena	n/a	n/a

Source: Seyam and others 2001.
n/a = No data available.

- economic valuation techniques;
- applicability of the techniques for wetlands and developing countries;
- issues of scale, time and discounting in calculating present value; and
- differences between wetland area and social impact area.

The estimated values recorded in the work Turpie and others (1999) need updating. Their analysis, however, still indicates types and range of resources that the wetlands provide, and also what the value is of a particular use or resource is in comparison to other derived from the wetlands. In terms of direct subsistence use from riverine wetlands, Seyam and others (2001) emphasize the importance of fishery, grazing, wildlife and agriculture among others (table 3.74.).

3.3.3 Barotse Floodplain

The Barotse Floodplain, also known as the Bulozi Plain or Lyondo, is flat and influenced by several river systems. Delineating its boundary can therefore be difficult (table 3.75.). Timberlake (2000) defined the area as extending from Lukulu to downstream of Senanga, and including the Liuwa Plain National Park, the Luena Flats, the Barotse Floodplain, and the Lungúe Bungo River wetlands. Turpie and others (1999) provide estimates of the area (table 3.75.), but focus on the Barotse Floodplain. The Barotse Floodplain was listed as a Ramsar site in 2007.

Table 3.75. Estimated area of the Barotse Floodplain extended wetlands (ha)

Wetland	Area
Barotse Floodplain	550,000
Lungúe Bungo wetlands	70,000
Luena Flats	110,000
Luanginga River	100,000
Liuwa Plains National Park	366,000
Total	**1,196,000**

Source: Turpie and others 1999.

Table 3.76. Approximate extent of different habitat types within the Barotse Floodplain

Habitat type	Percent coverage	Area (ha)
Palm savanna	2	11,000
Floodplain grassland	40	220,000
Wet grass	40	220,000
Reeds and sedges	10	55,000
River channel	8	44,000
Total	**100**	**550,000**

Source: Turpie and others 1999.

The Barotse Floodplain supports the three activities of direct use traditionally associated with floodplain dwellers and intimately linked to the occurrence of annual floods: fishing during flooding; movement of grazing cattle onto the drying land as floods recede; and fertilization of crops grown in the dry phase by manure from cattle.

Cattle begin moving onto the floodplain starting around June, with all cattle on the floodplain between August and December. The most cattle are on the higher ground from February to May, which is a time of stress and high mortality due to the poor quality of grazing food. A total of 435,000 cattle is estimated to be present on the floodplain in the dry season.

Most crops are grown on higher ground outside the floodplain, but farming and 'garden' areas within the floodplain support production of vegetables, fruit trees, maize, root crops, and rice. Croplands are prepared in October to January, grown from November to March/April, and harvested between March and May.

Fisheries are one of the most important sectors in the Western Province of Zambia. The Barotse Floodplain provides most of the catch. Bream constitutes 80 percent of the catch, with smaller numbers of tilapia, bottlenose, and other species. Fish move onto the floodplains between December and April and spawn in February and March before the flood peak. Fishing is very seasonal. The closed season is from January to March (now amended in some areas from December to February), and the most effective fishing season occurs when the floodwaters recede and concentrate the fish into smaller areas. Catches

Table 3.77. Wetland activities linked to Barotse Floodplain

Factor	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Flood season	▓	▓	░								░	▓
Fish on floodplain	▓	▓	▓	░								░
Maximum fish catch				░	░	░	░					
Crops on floodplain	░	▓	▓	▓	▓					░	░	░
Cattle on floodplain					░	░	░	▓	▓	▓	▓	▓
Reeds harvested					░	░	░	░	▓	▓	▓	░
Papyrus harvested	░	░	░	░	░	░	░	▓	▓	▓	▓	▓
Palm harvested	░	░	░	▓	▓	▓	▓	░	░	░	░	░
Clay harvested								░	░	░	░	░
Food scarcity	░	░									░	░

Time range = colored shade; peak time = dark shade.

Table 3.78. Current annual financial and economic direct use for the Barotse Floodplain ($, gross and net values)

Item	Financial gross value	Financial net value	Economic gross value	Economic net value
Livestock	3,323,048	3,323,048	3,987,657	3,907,518
Crops	2,357,041	2,341,396	1,297,197	–159,819
Fish	4,955,618	4,802,800	5,946,741	4,587,143
Birds	4,028	3,395	4,028	2,866
Turtles	7,947	7,894	,7,947	7,365
Reeds	134,983	30,907	161,979	135,202
Papyrus	130,714	126,164	156,857	111,549
Floodplain grasses	221,952	218,370	266,342	216,800
Grasses value added	5,714	4,285	5,714	3,750
Palms	2,169	1,818	2,169	944
Palms value added	9,661	5,597	9,661	2,313
Clay	57,391	57,083	57,083	46,483
Clay value added	8,570	7,285	8,570	5,276
Total	**11,520,000**	**11,174,000**	**12,244,000**	**8,647,000**

Source: Turpie and others 1999.
Note: Units are $ and for the whole wetland area. This is a very conservative estimate. Many uses are unknown or underreported.

are highest in the river channels between April and July. Higher flood levels, and possibly longer flood durations, are thought to increase fish productivity, as more spawning, feeding, and nursery grounds become available on the floodplains. Drought years can reduce availability of fish by up to 80 percent compared to good years, a situation exacerbated by overfishing.

Wild animals of all kinds are becoming progressively rare on the floodplains because of hunting, poaching, and habitat destruction. Efforts to reverse this trend include controlling hunting, nest thievery, and grass burning that destroys nesting sites. Lechwe and reedbuck are poached, turtle caught in fishing nets, and many bird species—including open-billed stork, geese, black stork, great white egrets, ducks, and cormorants—are hunted for food. Unrecorded harvesting of many species makes it likely that their values are considerably higher than estimated in this study.

Reeds, especially *Phragmites* spp., and sedges are used in construction of buildings, fences, mats, and fishing apparatuses. They are harvested as flood waters recede, increasing noticeably from June onwards and peaking between September and November. Papyrus(*Cyperus papyrus)* is the preferred material for sleeping mats and is also used in construction, roofing, and for coffins. The plants occur higher up the floodplain than reeds and can still be harvested in the flood season, although harvesting peaks from August to December. Grass is used for thatching, tying, weaving, and sometimes for fuel. It is unknown how much of the grass comes from the floodplain, but harvesting is highly seasonal, increasing in between March and May and peaking between July and September. Palm leaves of *Borassus* and *Raphia* are used in baskets, ropes, tying, and construction. Harvesting of leaves tends to increase in April, peaking between then and July, but remains at moderate levels year round. The floodplain produces little in the way of fuel wood. Clay is used in construction and for pottery and is considered one of the most important resources of the wetland for directly using communities. It is collected during the early rainy season, mostly from August to December.

Turpie and others (1999) tried to estimate the financial value of indirect use of the Barotse Floodplain. In table 3.79., figures are provided for ecosystem services such as groundwater recharge or water purification. The accuracy of these estimates is extremely difficult to confirm and they do not include assessment of values incorporated into direct use.

Table 3.79. Minimum value of the indirect uses of the Barotse Floodplain (estimated net present value of ecosystem services)

Indirect use	Value ($ million/year)
Flood attenuation	0.4
Groundwater recharge and water supply	5.2
Sediment retention	Medium importance (not estimated)
Water purification	11.3
Shoreline protection	n/a
Carbon sequestration	27
Commercial fisheries	Not included
Tourism	Not included
Minimum total estimate	**43.9**

3.3.4 Eastern Chobe-Caprivi Wetlands

From Katimo Mulilo in the west to Kazungula in the east, the Zambezi River forms a series of interlinked floodplains along the borders between Namibia, Zambia, and Botswana. The floodplain system in Eastern Caprivi covers approximately 370,000 hectares, linking the Kwando/Cuando, Linyanti, Chobe, and Zambezi rivers. The area of the wetlands used in the Turpie and others (1999) study is located in the Kabe constituency, in extreme eastern Caprivi. The border of Botswana forms the study area's boundary along the Chobe River and then extends into Zambia. The surface area of this part of the wetlands is approximately 220,000 hectares, with the same range of habitats as the Barotse Floodplain. Floods depend on water arriving from the upper catchments and are often delayed until these areas receive heavy rainfall.

Among the direct uses of the wetlands, one of the most important is cattle grazing. The eastern

Table 3.80. Approximate study area of different habitat types within the Eastern Chobe-Caprivi Wetlands

Habitat type	Percent coverage	Area (ha)
Palm savanna	2	4,400
Floodplain grassland	70	154,000
Wet grass	15	33,000
Reeds and sedges	8	17,600
River channel	5	11,000
Total	**100**	**220,000**

Source: Turpie and others 1999.

Caprivi floodplain grasslands are home to about 124,000 cattle, a third of which move to higher ground during the peak flood season (March to June). Their value on the floodplain is mostly linked to milk, other production and plowing. Locally, fertilizers are not considered important though cattle is a vital source of wealth providing owners with a drought-coping strategy, access to community rights, as well as other intangible benefits such as ceremonial.

Maize is grown in the wetter floodplain areas as floodwaters recede, and millet and sorghum on drier lands. Other minor crops are potatoes, vegetables, beans and other legumes, pumpkin, melons, and groundnuts, and beer is brewed from grains. The clay-rich soils of the floodplain combined with a good flooding regime and nutrient balance provide moderately good soils for crops. The area thus provides adjacent rural areas with some level of food security.

Most fishermen in the area belong to the Subia tribe, which traditionally live on the floodplain. Fish is one of the most important sources of protein and is eaten most days of the year. Outside the flood season, fishing is confined to man-made canals, and the Zambezi and Chobe rivers. Good catches are correlated with years of high rainfall and high floods, and poor catches with drought years.

Populations of large mammals have declined drastically in numbers over the last 20 years, especially those associated with wetlands such as sitatunga, Lechwe, sable, reedbuck, bushbuck, and waterbuck. For example, the Lechwe has declined from over 11,000 in the early 1980s to just a few hundred in 1995 due to increased hunting, habitat loss, and habitat changes due to lower rainfalls. Lechwe, sitatunga, and occasionally hippopotamus are still hunted, but larger wild animals are scarce. Illegal poaching of small antelope occurs in the adjacent Chobe National Park. Wildlife from the National Park, in turn, may move across the border, destroying crops and nets and killing livestock (and sometimes people). Waterbirds, such as ducks, geese, reed cormorants and darters, and their eggs, are also hunted for food.

Reeds are used for house construction, fences, fish baskets and traps, fish spears and rods, and handicrafts. They are gathered from low-lying wetland areas, particularly from the banks of the main river channels and the secondary channels that cover the floodplain. Harvest occurs mainly in July and August at the beginning of the dry season when floodwaters are receding and before the main burning season. Papyrus is used for mats for sleeping, sitting, drying crops, and as a frame for roofs. Grass is used for thatching and is harvested mostly in July when the floodwaters recede and before the burning season. Palm leaves, whose uses are unknown, are harvested mainly in August after the floodwaters have receded. In addition, several wild food plants are harvested. Water lily bulbs, located in marshy permanent pool areas on the floodplain, are a carbohydrate substitute when food supplies are low. Plants provide food, cooking supplements and medicines. They are mostly harvested in July as the floodwaters recede and people can move over the wet floodplain and through shallow pools. Dugout canoes (*mikoro)* are used for fishing and are mostly made from Kiaat (*Pterocarpus angolensis)* and Rhodesian Teak (*Baikiaea plurijuga).*

Most activities are linked to the annual flood pulse (table 3.81.). Fish move onto the floodplain to spawn in February and March and then back into the river channels beginning in October. Cattle, in turn, move onto the floodplain as the floods subside. The timing of crop harvesting is unknown but probably occurs just before the floods begin. Natural plant resources, such as reeds and papyrus, are harvested at the end of the flood season, after they have enjoyed maximum growth in favorable wet conditions.

Table 3.83., provided by Turpie and others (1999), lists the estimated value of indirect uses. Readers are directed to that publication for further details. The figures do not include assessment of values incorporated into direct use.

3.3.5 Kafue Wetlands

The Kafue River is a major tributary of the Zambezi River. Its drainage basin lies entirely within Zambia and provides 40 percent of the country's potable water including being the major water source for the capital Lusaka. It includes three important wetlands, the Busanga swamps, the Lukanga swamps and the Kafue Flats. While there is little information available from the Busanga and Lukanga swamps, extensive research has been done on the Kafue Flats. The Kafue Flats, upstream of Kafue Gorge, is a broad

Table 3.81. Wetland activities linked to the Eastern Chobe-Caprivi Wetlands annual flood pulse

Factor	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Flood season		░	░	░	░	░	░					
Fish on floodplain		░	░	░	░	░	░	░	░	░		
Maximum fish catch		░	▓	▓	▓	▓	▓	▓	▓	▓		
Cattle on floodplain	░	░					░	░	░	░	░	░
Reeds harvested							░	░				
Grass harvested							░					
Palm harvested								░				
Wild plants harvested							░	░				

Time range = colored shade; peak time = dark shade.

Table 3.82. Current annual financial and economic direct use values for the Eastern Chobe-Caprivi Wetlands ($, net and gross)

Item	Financial gross value	Financial net value	Economic gross value	Economic net value
Livestock	1,944,272	1,944,272	2,060,928	1,830,961
Crops	970,162	945,569	712,889	–3,962,030
Value added – beer brewing	40,438	35,324	40,209	23,547
Fish	1,491,641	1,034,285	1,581,139	694,415
Wild animals including birds	225,565	219,385	219,385	215,723
Reeds	165,865	163,680	175,817	154,456
Papyrus	175,714	173,578	186,256	177,003
Papyrus value added	67,879	61,286	71,952	46,650
Floodplain grasses	129,786	128,935	137,573	129,660
Palms	16,187	14,926	16,187	5,040
Wild food plants	49,293	49,228	49,293	23,369
Total	**5,277,000**	**4,770,000**	**5,277,000**	**4,770,000**

Source: Turpie and others 1999.
Note: Units are $ and for the wetland area studied. This is a very conservative estimate. Many uses are unknown or underreported.

alluvial plain, about 250 kilometers long, 60 kilometers wide, and covering around 650,000 hectares. The retention time for water passing through the Flats is about two months. Under natural conditions, water levels start to rise in December and peak between March and May; by October the floodplains and seasonal swamps would be dry. In the region, the Kafue Flats has some of the most biologically diverse ecosystems within its meandering river channels, lagoons, ox-bow lakes, remnant secondary channels, marshes, levees, and flooded grasslands. Among others, it supports more than 400 bird species, numerous fish species and substantial mammal populations such as the Kafue lechwe *Kobus leche kafuensis*. The Kafue Flats was listed as a Ramsar site in 1991. Most information cited for the Kafue Flats wetlands is from McCartney, Sullivan, and Acreman (2000) unless indicated otherwise.

In 1971 the Kafue Gorge Upper Dam (KGU) was built downstream of the Flats to produce hydropower (990 MW capacity). To improve energy production targets through a regulation of inflow, the Itezhi Tezhi Dam (ITT) was built upstream of the Flats in 1977. To reduce any negative impact of

Table 3.83. Minimum value of the indirect uses of the Eastern Chobe-Caprivi Wetlands (estimated net present value of ecosystem services)

Wetland product	Value ($ million/year)
Flood attenuation	Low
Groundwater recharge and water supply	0.5
Sediment retention	8.9
Water purification	1.6
Shoreline protection	n/a
Carbon sequestration	11.0
Commercial fisheries	Not included
Tourism	Not included
Minimum total estimate	**22.0**

ITT Dam on the Kafue Flats (through insufficient magnitude and timing of floods), extra storage was built into the Itezhi Tezhi reservoir specifically for the purpose of releasing water for restoration of natural floods. Since then, some variability of flows from ITT into the Flats has been ensured although the general trend has been lower flood flows and shorter duration than the natural flood levels and cycles. As flooding patterns have been altered, less frequent flooding occurs in the west of the Kafue Flats and more in the east where additional permanent water areas have formed.

The majority of people living on the Flats obtain water from wells, boreholes, and streams, and between 70 and 90 percent rely on firewood for energy. Grazing areas for livestock have been reduced, in the west due to desiccation and in the east because of inundation. Cattle grazing has also been negatively affected by problems such as the terminal tick-borne "corridor disease" (theileriosis) killing thousands of cattle. The spread of the disease is thought to have been caused by the reduced flooding regimes that previously controlled tick numbers.

There has been some decline in fish catches since the construction of the Itezhi Tezhi Dam in 1977, and some decline in the number of people actively fishing, but the Flats still provides about 7,000 tons of fish per year and the Itezhi Tezhi reservoir another 2,000 tons. Seyam and others (2001) used a rapid desktop approach to assess the direct use values of the wetlands in the Zambezi River Basin using 1990 market values. They used a sliding scale of areas contributing to the values with protected areas assigned 90 percent, partly protected areas 10 percent, and unprotected areas zero percent. Their values for the Barotse Floodplain, Chobe-Caprivi Wetlands, and Lower Shire Wetlands were quite different from those of the more detailed work by Davies, Beilfuss, and Thoms (2000). A major reason being that they considered different surface areas for the same wetlands, for example 900,000 hectares for Barotse Floodplain as opposed to 550,000 hectares in Turpie and others (1999). Even accounting for that difference, values still differed by up to four orders of magnitude in the two studies, with neither study having values consistently higher or lower than the other. Nevertheless, as these are the only figures available, they are reproduced in table 3.84. Indirect values of the Kafue Flats includes resources such as aquifer recharge, flow regulation, inputs and retention of nutrients and soils, navigation and communication, drought survival and maintenance of water quality though these are not estimated in detail (Timberlake 2000).

Table 3.84. Direct use value of the Kafue Flats Wetlands (rapid desktop approach)

Wetland product	Value ($ million/year)
Crops	8.30
Fish	13.30
Wildlife	0.01
Cattle	2.40
Natural products and medicines	4.26
Total	**28.27**

Source: Seyam and others 2001.

3.3.6 Lower Shire Wetlands

The Lower Shire wetland area extends from Kapichira Falls near Blantyre, Malawi, to the confluence of the Shire River with the Zambezi River near Caia, Mozambique. It includes Elephant Marsh and Ndinde Marsh, with additional minor wetland areas (table 3.85.). Literature on the area is sparse and mostly outdated.

The Lower Shire Wetlands are not well protected and appear to be shrinking because of dropping

Table 3.85. Estimated area of the Lower Shire Wetlands

Wetland	Area (hectares)
Elephant Marsh	60,000
Bangula Marsh	17,000
Ndinde Marsh	80,000
Tributary marshes	5,000
Total	**162,000**

Source: Turpie and others 1999.

water levels in Lake Malawi/Niassa/Nyasa; only Ndinde Marsh is a reasonably intact ecosystem. They support the same broad categories of habitat types as the other wetlands discussed above (table 3.86.).

The area receives summer rainfall, with flooding usually beginning in late January or February. During periods of high runoff from the local catchments corresponding with floods in the Zambezi River, the Shire River backs up from the Zambezi confluence to north of Elephant Marsh with widespread local flooding.

Like in other areas of the Basin, the wetlands are directly valuable for cattle grazing. Cattle graze in both the uplands and wetlands and move along the floodplain margins as floodwaters recede. Dambos are also used for dry-season grazing and in drought years. Cattle are moved to higher ground during the flood season and before the crop-planting season. An estimated 104,450 cattle feed on the floodplain, where they spend an average of seven months per year.

Table 3.86. Approximate area of different habitat types within the Lower Shire Wetlands

Habitat type	Percent coverage	Area (ha)
Palm savanna	2	3,240
Floodplain grassland	20	32,400
Wet grass	45	72,900
Reeds and sedges	27	43,740
River channel	6	9,720
Total	**100**	**162,000**

Source: Turpie and others 1999.

Most of the area is under small-holder farming. Elephant Marsh becomes very dry in below-average rainfall years and is used almost entirely for cultivation. Cropping patterns vary considerably from year to year depending on soil moisture content, among other factors. Major crops grown on the marshes are maize, sorghum, millet, beans, rice, cotton, cassava, and Irish potatoes. Maize yields are below the national average, possibly due to a relatively unfavorable climate. Commercial estates and irrigation schemes are common. In some areas, irrigation supports two crops per year. There is some evidence that soil fertility is decreasing. Links with the traditional pattern of flood-recession agriculture appear to be weakening.

The Lower Shire Wetlands are second only to Lake Malawi/Niassa/Nyasa in the number of exploitable fish species. The shallow floodplains are used for breeding and any reduction in that area would constitute a threat to commercial activities. Most fishing occurs on the floodplains from April to July in receding floodwaters, with a lesser amount of fishing in the Shire River channels and permanent lagoons such as Lisuli (north end of Elephant Marsh) during the dry season (November to January). Three fish species make up 90 percent of the catch: two catfish species, *Clarias gariepinus* and *C. ngamensis*, and the cichlid *Sarotherodon mossambicus.*

As in other wetlands, the population of large mammals—such as sitatunga, lechwe, sable, reedbuck, bushbuck, waterbuck, and elephant—has declined drastically over the last century. At least 64 species of birds still use Elephant Marsh. Most hunting is of small animals, such as hares, rats, doves, guinea fowl, and wild pigs.

Reeds and papyrus have the same uses as described for other wetlands. Low flood seasons and exceedingly high floods reduce their abundance. The plants are harvested at the end of the flood season, mostly in July to September. By October most reed beds and papyrus beds have been eradicated by harvesting or burning in preparation for crops. Floodplain grasses are used as described earlier and harvested mainly from June to September as floodwaters recede. Palms are rarely used. Other plants are harvested from the floodplain including:

lily bulbs for carbohydrates and plants for cooking relish; and wild millet, fruits, roots, leaves and bark for uses such as medicines. Harvesting occurs mainly after the floodwaters recede and into the dry season, providing an important food source at the end of the dry season when grains are in short supply. As with other wetlands, activities are closely linked to the annual flood pulse (table 3.87.). Most activities cease on the floodplain during the height of the floods and then gather momentum as the floodwaters recede.

Table 3.89. are quoted from the work of Turpie and others (1999).

3.3.7 Luangwa Wetlands

The Luangwa Wetlands cover 250,000 hectares along the Luangwa River in northern Zambia. The wetlands were listed as a Ramsar site in 2007. The Luangwa River is unregulated and pristine, meandering between sandy banks in the dry season. In the wet season its width spreads to several kilometers, filling ox-bow lakes and dambos and flooding grasslands. The ecoregion supports important populations of large mammals and reptiles, more than 60 fish species, and several hundred bird species. Much of the Luangwa Valley is formally

Table 3.87. Wetland activities linked to Lower Shire Wetlands annual flood pulse

Factor	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Flood season	░	░	▓	▓	░	░						
Fish on floodplain		░	░	░	░	░	░	░				
Maximum fish catch				░	░	░	░					
Cattle on floodplain					░	░	░	░	░	▓	▓	░
Reeds harvested				░	░	░	▓	▓	▓	░		
Grass harvested				░	░	▓	▓	▓	▓			
Wild plants harvested					░	▓	▓	▓	▓	▓	▓	░

Time range = colored shade; peak time = dark shade.

Table 3.88. Current annual financial and economic direct use values for the Lower Shire Wetlands ($ gross and net)

Wetland product	Financial gross value	Financial net value	Economic gross value	Economic net value
Livestock	1,769,877	1,769,877	2,123,853	2,006,150
Crops	17,273,419	17,100,408	15,518,227	13,270,048
Fish	3,272,078	1,724,534	3,926,494	1,008,861
Wild animals including birds	55,127	13,636	55,127	10,372
Reeds and papyrus	292,451	283,755	350,942	298,302
Papyrus value added	564,985	371,509	677,982	427,302
Floodplain grasses	1,873,055	1,866,716	2,247,667	2,169,422
Grasses value added	4,493	1,661	5,392	1,866
Palms	41,489	4,802	49,787	1,664
Wild food plants	407,206	385	882	407,206
Clay	468,379	140,347	562,055	223,848
Total	**24,943,000**	**23,865,000**	**24,630,000**	**19,854,000**

Source: Turpie and others 1999.
Note: Units are $ and for the wetland area studied. This is a very conservative estimate. Many uses are unknown or underreported.

Table 3.89. Minimum value of major indirect uses of the Lower Shire Wetlands (estimated net present value of ecosystems services)

Indirect use	Value ($ million/year)
Flood attenuation	2.7
Groundwater recharge and water supply	7.5
Sediment retention	Low
Water purification	18.4
Shoreline protection	n/a
Carbon sequestration	8.0
Commercial fisheries	Not included
Tourism	Not included
Minimum total estimate	**36.6**

Table 3.90. Direct use value of the Luangwa Wetlands (rapid desktop approach)

Wetland product	Value ($ million/year)
Crops	3.20
Fish	5.10
Wildlife	0.00
Cattle	0.90
Natural products and medicines	1.64
Total	**10.84**

Source: Seyam and others 2001.

protected as national parks and game management areas. Human population density is thought to be low. No detailed information is available on the direct use values, indirect use value, or existence value[19] of the wetland area. However, Seyam and others (2001) performed a rapid desktop analysis so as to make rough estimates of the value of a number of key wetland products, such as the approach to analyzing the values within the Kafue Flats.

3.3.8 Zambezi Delta

The Zambezi Delta has an area of 1.4 million hectares, extending over a triangular area from Mopeia in Mozambique 120 kilometers downstream to the coast, and between the Rio Cuacua in the north and the Mungari River in the south. It includes the 150,000 hectare Marromeu Complex and Buffalo Reserve, which was designated Ramsar site in 2004. The Delta used to support mangrove swamps as well as the same broad habitat types as the other wetlands described above (table 3.91.). The original flooding pattern of high waters between January and April and low waters between October and November has been changed because of upstream dams that now regulate 70 percent of the Basin. Initially, the Kariba Dam reduced downstream flooding, which desiccated the Delta's alluvial soils, causing salinization and terrestrialization of the floodplain. Cahora Bassa Dam amplified the transformation of the flow regime, drastically reducing the magnitude of annual downstream flooding thereby severing the connection between the river and its floodplain. It is also believed that due to absence of natural or artificial flooding of sufficient magnitude and timing, the salinity and thus conductivity of the Shire River has increased.

There are very few subsistence cattle farmers in the Zambezi Delta wetland area, and no recorded estimated values of cattle present. Subsistence farming is on the other hand common in the Delta, and an estimated 110,000 hectares of land are under cultivation. Rice is the dominant crop, followed by maize, sweet potatoes, cassava, sorghum, millet,

Table 3.91. Approximate area of different habitat types within the Zambezi Delta

Habitat type	Percent coverage	Area (ha)
Palm savanna	5	63,750
Floodplain grassland	40	510,000
Wet grass	25	318,750
Reeds and sedges	10	127,500
River channel	5	63,750
Mangroves	15	191,250
Total	**100**	**1,275,000**

Source: Turpie and others 1999.

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[19] Existence value refers to the recognition of the value of the existence of the wetlands (WWF 2004).

sugar, beans, and tobacco. Rice is commonly grown on river banks that have been cleared of mangroves; maize is sowed on higher ground between October and December and on lower ground in June and July.

Fish is an important part of the diet of communities living in and near the Zambezi Delta. The catfish *Clarias gariepinus* and cichlids such as *Tilapia* and *Saratherodon* species account for about 90 percent of the catch. Fishing on the floodplain peaks in August to December when the floodwaters have receded, but peaks earlier in the river channels; at the coast fishermen move from wetland to coastal fisheries around June as catches decline in the river. Fish catches at the coast are about 37 percent from the sea and 24 percent from the estuary with the remainder from freshwater. In the inner delta, more fish are harvested from the rivers (approximately 60 percent) than from the floodplains (the other 40 percent). In all areas, good floods equate to high fish catches, though there is a local perception that catches have decreased since the construction of the Cahora Bassa Dam.

Animal numbers have been severely reduced over the last two decades, and wildlife will need active management to recover in the face of a desiccated floodplain and hunting pressure. Wild plants are used for construction, thatching, medicines, firewood, wine-making, and cooking similar to other wetland areas. Demand for these plants is greatest between December and February, to compensate for subsistence needs prior to crop harvesting. The uses for reeds, papyrus, and grasses are the same as in other wetland areas. In the Zambezi Delta, there are two types of forest with a range of direct values and uses:

- Mangroves are important natural areas for coast protection, moderating the effects of storms, providing habitat for commercial fish species, absorbing pollutants, and providing high quality timber, charcoal, firewood, and opportunities for recreation and tourism. There are 5,500 hectares of mangroves in the Delta, but this area is declining due to over-harvesting and changes in flow and sediment regimes brought about by upstream dams.
- Palm trees (*Borassus aethiopum*) and *Hyphaene coriacea* are of great use in the inner parts of the Delta. On the coast, *Phoenix reclinata* and the exotic coconut palm (*Coceira* sp. *Borassus*) extend over a 65,000 hectares area as part of a mosaic of grasslands, woodlands and agricultural areas. Palm has many uses, among which are production of planks, roofs, mats, hats, baskets, and wine.

The figures in table 3.94. are provided Turpie and others (1999).

Table 3.92. Summary of available information on wetland activities in the Zambezi Delta

Factor	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Natural flood season (substantially curtailed)	▨	▨	▨	▨								▨
Fish catch on floodplain								▨	▨	▨	▨	▨
Fish catch in rivers				▨	▨	▨	▨	▨	▨	▨		
Fish catch in marine areas						▨	▨	▨	▨	▨		
Crops sown (maize)						▨	▨			▨	▨	▨
Reeds and grasses harvested					▨	▨	▨	▨	▨			
Wild plants harvested (inner delta)	▨	▨									▨	▨
Wild plants harvested (outer delta)	▨	▨	■	▨	▨	▨	▨	▨	▨	▨	▨	▨

Time range = colored shade; peak time = dark shade.

Table 3.93. Current annual financial and economic direct use values for the Zambezi Delta ($, gross and net)

Wetland product	Financial gross value	Financial net value	Economic gross value	Economic net value
Livestock	0	0	0	0
Crops	7,433,581	7,422,633	7,442,792	3,788,869
Freshwater and estuarine fish	4,995,365	4,791,841	5,994,438	5,225,777
Crustacean (prawns, crabs)	1,125,814	1,075,295	1,350,977	1,226,724
Wild animals including birds	27,083	11,964	27,083	4,570
Mangroves	127,787	107,668	153,345	107,149
Palms	581,159	566,071	661,937	579,436
Palms value added	116,068	79,881	123,414	41,757
Reeds and papyrus	108,229	66,805	108,229	43,862
Papyrus value added	479,506	179,788	479,506	118,685
Floodplain grasses	361,648	360,516	433,978	370,532
Wild food plants	252,432	251,157	252,432	240,001
Clay	4,808	4,808	4,808	3,939
Total	**15,609,000**	**14,914,000**	**17,028,000**	**11,747,000**

Source: Turpie and others 1999.
Note: Units are $ and for the wetland area studied. This is a very conservative estimate. Many uses are unknown or underreported.

Table 3.94. Minimum value of the indirect uses of the Zambezi Delta (estimated net present value of ecosystems services)

Indirect use	Value ($ million/year)
Flood attenuation	Medium
Groundwater recharge and water supply	3.2
Sediment retention	Medium
Water purification	12.7
Shoreline protection	Medium
Carbon sequestration	64.0
Commercial fisheries	Not included
Tourism	Not included
Minimum total estimate	**79.9**

Source: Turpie and others 1999.

3.3.9 Summary of values

Table 3.95. summarizes various use values in the Zambezi wetlands. All are rough estimates, and are probably strong underestimates due to the paucity of data, lack of coverage of the Zambezi system, and underreporting (especially regarding illegal activities such as poaching).

3.4 TOURISM

3.4.1 Tourism in Africa

According to the World Tourism Organization (WTO 2005), international tourist arrivals worldwide reached 919 million in 2008, an increase from 682 million in 2000. The total exceeded all expectations. Worldwide, international tourism receipts totaled some $942 billion in 2008. Over the same time period, 2000–2008, tourism arrivals to Sub-Saharan Africa increased from 15.9 to 27.4 millions. Growing peace, political stability and prosperity is generating larger numbers of affluent and experienced tourists in search of more original and more exciting destinations. Africa has grown more prosperous, with a real GDP increase of around 5.5 percent a year in both 2004 and 2005. That growth has generated local and long-haul demand for business and leisure travel. Many destinations report increased funding for tourism promotion and

Table 3.95. Use values in Zambezi System Wetlands (summary of direct use values for six wetlands in the Zambezi River system; and indirect use and existence values for four wetlands)

Attribute	Barotse	Chobe-Caprivi	Kafue Flats	Lower Shire	Luangwa Wetlands	Zambezi Delta
Area of study (ha)	550,000.0	220,000.0	650,000.0	162,000.0	250,000.0	1,275,000.0
Direct use value ($ million)	11.0	5.0	28.3	24.0	10.8	15.0
Indirect use value ($ million)	43.9	22.0	—	36.6	—	79.9
Total annual value ($ million)	55.0	27.0	—	61.0	—	96.0
value/ha($)	100.0	123.0	—	377.0	—	75.0
Existence value ($ million)*	4.2	1.7	—	1.2	—	9.7

Source: The data for the wetlands of the Barotse Floodplain, Chobe-Caprivi, Lower Shire and the Zambezi Delta is taken from Timberlake (2000) and from Seyam and others (2001) for the Kafue Flats and the Luangwa Wetlands.

*Values estimated by area as proportion of that for Barotse.

better cooperation between the public and private sectors. New tourism products, such as business tourism, cultural tourism, ecotourism, and sports tourism, are opening up new markets around the world. More African countries have negotiated Approved Destination Status agreements with China and market expectations are high.

Significance of tourism in Sub-Saharan Africa

According to World Travel and Tourism Council (WTTC 2006), tourism remains a major contributor to the economies of Sub-Saharan Africa. As a contributor to GDP however, tourism is expected to decline from 7.9 percent ($71.4 billion) in 2008 to 7.4 percent ($136.9 billion) by 2018.

Its contribution to employment is also expected to fall, from 5.6 percent of total employment as of 2008 (one in every 17.9 jobs) to 4.9 percent by 2018 (1 in every 20.3 jobs). Exports earnings from international visitors and tourism goods are expected to generate 12.6 percent of total exports ($42.7 billion) in 2008, growing in nominal terms to $76.2 billion (12.8 percent of total) in 2018.

Significance of tourism in the Zambezi River Basin

In 2007, total annual direct value of tourism in the ZRB alone was estimated at $443 million (or $457 million with hunting included) (WTTC 2006; Dencon-sult 1998b). According to the WTO 2005, tourism in Sub-Saharan African region grew at more than nine percent annually between 1995 and 2005. Based on the above figures and an inflation rate of two to three percent per year over the last 13 years (expressed in US dollars), and an average growth in tourism of between seven and ten percent the tourism industry could currently be anywhere between $1.4 billion and $2.3 billion. In other words, the Zambezi River Basin could be accounting for between 12 percent and 20 percent of the tourism economy of member countries. That total could vary substantially among countries. In Angola, for example, very few tourists visit areas in the Zambezi River Basin. In Zambia, on the other hand, an estimated 54 percent of tourists primarily want to see Victoria Falls and another 34 percent want to experience wildlife, adventure activities, and hunting in areas that mostly fall within the Zambezi River Basin (Hamilton and others 2007).

Among the riparian countries, Botswana has the highest number of international arrivals, but the lowest number of beds and the smallest percentage of non-African visitors, which suggests that many tourists are visiting friends or relatives or doing day visits. Zimbabwe has the second largest number of international arrivals, followed by Namibia. Tanzania has the largest number of recorded rooms, followed by Malawi and Mozambique. Malawi has the highest recorded nights spent by tourists, followed by Tanzania. Statistics on nights spent are incomplete and unreliable, as some recorded nights are spent in collective accommodation (which includes friends and relatives), while others do not. Tanzania recorded the highest total receipts from international tourism and the highest earnings per international visitor, followed in both categories by Botswana and Namibia.

3.4.2 Effects from water extraction for tourism

The area of the ZRB that lies within Angola will not be affected significantly by any water extraction or change in flow levels considered in this study. It therefore will not receive significant further attention. Likewise, the area of the Basin that lies within Tanzania is not expected to be affected by reservoirs or water extraction considered in this study.

The Zambezi River Gorge between Victoria Falls and Lake Kariba—an important tourist area—would be severely affected by the planned Batoka Dam project. Furthermore, the planned irrigation schemes and water extraction for Gaborone at Caprivi could have a severe impact on tourism related to Victoria Falls. Some further discussion follows on the importance of maintaining natural flows at Victoria Falls to preserve its tourism appeal.

Very few tourists visit the portion of the Basin within Mozambique, and this trend is expected to continue for foreseeable future. In the case of Malawi, the effect of water extraction on tourism areas upstream of Lake Malawi/Niassa/Nyasa is expected to be limited as there are no plans to build the High Kholombidzo Dam that would fully regulate the Lake. Planned irrigation schemes at Caprivi and water extraction for Gaborone could have negative impact on water resources for tourism on the Chobe-Caprivi-Liambezi floodplain.

3.4.3 Tourism in the subbasins and possible effects from changes in water flow

The analysis and assessment of tourism and its value in the ZRB is based evaluations of available reports and information. The impact of possible water extraction and/or diversion sites will require further verification at each location to verify and further quantify possible impacts.

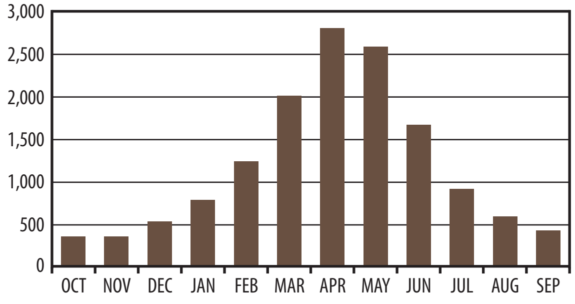
The Caprivi/Chobe/Kasane/Victoria Falls area in the Upper Basin is the most significant tourism destination in the entire Zambezi River Basin. Based on the assumption that water will be extracted from the Caprivi area for irrigation and for providing Gaborone with water, the impact on the Chobe-Caprivi area is not expected to be too damaging. The impact on Victoria Falls, however, could be severe.

The area around Livingstone and Victoria Falls accounts for 56 percent of the tourism accommodation capacity (1,704 beds), 46 percent of the total bed-nights in nature-based tourism establishments and the second highest turnover rate of visitors in Zambia. In 2005, it generated $38 million annually and employed 435 permanent staff (Pope 2005a).

The peak tourism season (during the more pleasant winter months of June to August) does not coincide with either the mean flow peak season (March to May) or with the peak rainy season (September to December) (figure 3.5.).

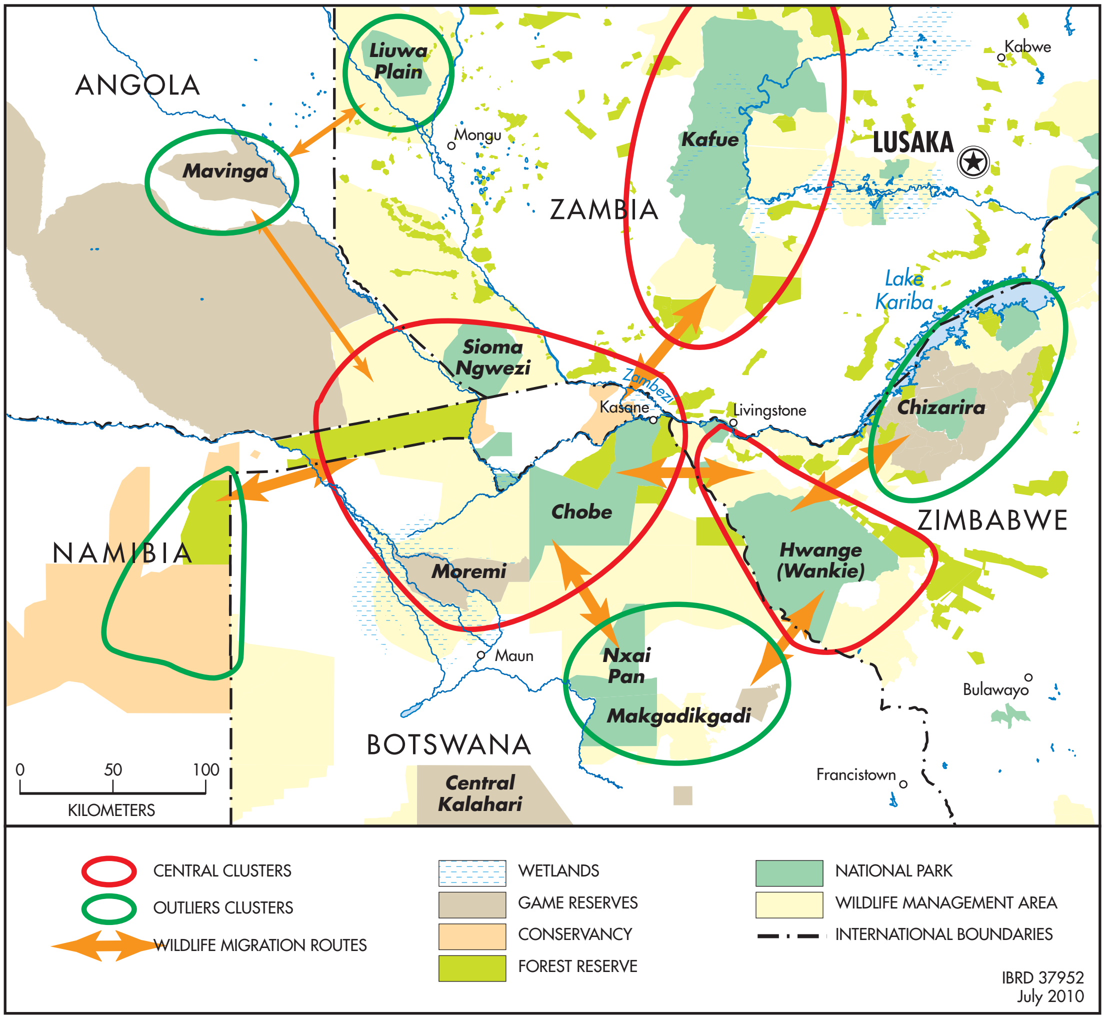
The Kavango-Zambezi Transfrontier Conservation Area (KAZA TFCA) tourism project is a cooperative effort among five countries—Angola, Botswana, Namibia, Zambia, and Zimbabwe. The KAZA TFCA in southern central Africa covers an area of 400,000 km^2. The Victoria Falls is a central point in the TFCA near the meeting point of four of the five participating countries (figure 3.6.). Two major river basins, the Zambezi and the Okavango, contribute major wetlands, including the Okavango Swamps, to the gently undulating KAZA TFCA landscapes (Cumming 2008).

Figure 3.5. Flow regime in Victoria Falls (m^3/s)



Source: FAO 2008b.

Figure 3.6. Map of the Kavango-Zambezi Transfrontier Conservation Area



Source: Conservation International 2008.

The mission of the participating countries is: "to establish a world-class transfrontier conservation area and tourism destination in the Okavango and Zambezi river basin regions of Angola, Botswana, Namibia, Zambia and Zimbabwe within the context of sustainable development" (MoU, December 2006). The primary objectives are to: foster transnational collaboration and cooperation in implementing ecosystems and cultural resource management; promote alliances in the management of biological and cultural resources and encourage social, economic and other partnerships among their governments and stakeholders; enhance ecosystem integrity and natural ecological processes by harmonizing natural resources management approaches and tourism development across international boundaries; develop mechanisms and strategies for local communities to participate meaningfully in, and tangibly benefit from, the TFCA; and, promote cross-border tourism as a means of fostering regional socioeconomic development. This transfrontier conservation effort will directly rely on the availability, quality and sustainability of its water resources. This is particularly true for the wetland areas where biodiversity and ecosystems are highly sensitive and interlinked with its waters.

The financial implications of tourism in the KAZA TFCA are considerable (Suich and others

2005). In 2004, accommodation establishments in the conservation region had a combined capacity of 8,312 guests per night. The total revenue generated by accommodation establishments and tour operations exceeded $100 million. In the same year, the tourism industry employed a total of 5,204 local workers, 689 of them in part-time jobs. Promoting integrated catchment management, for sustaining necessary water resources, to the relevant authorities will be vital part of KAZA TFCA's work. It will also be necessary to consider land use changes in the high water-yielding upper reaches of the major rivers flowing into the KAZA TFCA and explore incentives (such as payments for ecosystem services) for those in the upper catchments to maintain equitable water flows into the future. Land use practices that degrade wetlands within the KAZA TFCA must also be minimized.

As part of the MSIOA, the relationship between water management, the environment, and tourism was evaluated. Though seen as given to all scenarios developed by the models, environmental flows were explored in particular by introducing two scenarios: one for the low waters season allowing the maintenance of a minimum flow; and the other for the flood season ensuring that natural floods are only reduced to a certain extent (that is, not beyond a fixed percentage).

The reliability of these scenarios depend on the amount and quality of available data and knowledge for the geographic areas considered as well as the economic dimensions of tourism. It should also be noted that information on tourism is more readily available for Victoria Falls and in the outer Zambezi Delta compared to in other parts of the Basin. The relationships between water management, the environment, and tourism have large scale, multifaceted and complex dimensions. There is therefore an urgent need for more investment in information gathering, monitoring, and capacity.

- *Lower Victoria Falls.* The area between Victoria Falls and Lake Kariba is an internationally recognized whitewater rafting area. The proposed Batoka reservoir 65 kilometers downstream of Victoria Falls is expected to have a major effect on the whitewater potential of the Gorge as it may dam water back up the river towards the falls. According to Denconsult (1998c), the minimum flow for successful whitewater rafting is 500 m^3 per second. The dam operators claim that they need a flow for the first 30 kilometers downstream from Victoria Falls and they operate for 365 days of the year. According to Pope (2005a) more than 34,402 visitors go whitewater rafting on this stretch each year at the Zambian side. Each visitor spends an average of $135 per excursion (excluding accommodation) which means total annual revenues from the excursions is more than $4.5 million. If two night's accommodation in the area is included, with an average cost of $200 per night, whitewater rafting tourists in this area on the Zambezi side generates well over $10 million per year.

Therefore, if the Batoka reservoir dams the water more than 35 kilometers upstream, the entire whitewater rafting operation will be closed down, with an estimated loss of $10 million to the economy each year.

- *The Kafue Flats*, which also includes the renowned Kafue National Park, already has a dam at Itezhi Tezhi. Although some improvements to the dam—such as new turbines—are planned, the changes are not expected to alter flows and should have no further effect on the natural environment and tourism in the area. An additional reservoir below the existing Kafue Gorge Upper reservoir, the Kafue Gorge Lower, is planned. This area is not a tourism area, and no impact on tourism is expected.
- *Luangwa National Park, Lake Kariba, and Mana Pools.* Luangwa North and South National Parks, Lake Kariba, and Mana Pools are some of the most important tourism attractions in the middle Basin. No new water extraction or damming projects are planned for this area.
- *Lake Malawi/Niassa/Nyasa.* The primary tourism attraction in the Lower Basin is Lake Malawi/Niassa/Nyasa. The Malawi Ministry of Tourism, Wildlife and Culture reports that future tourism projects are planned, including conference resorts, lodge additions and upgrades on the lakeshore and in Blantyre (Republic of Malawi 2008). The areas upstream of Lake Malawi/Niassa/Nyasa are not significant for tourism.

- *Shire River.* Liwonde National Park, south of Lake Malawi/Niassa/Nyasa on the Shire River, offers bird watching, boating safaris, and game drives. In the extreme south, Lengwe National Park is popular for hiking and bird watching (Republic of Malawi 2008). The Shire River is also a popular sport fishing area. There are other reservoirs under consideration for the Shire River though the sites appear to fall outside protected areas and are not expected to have a significant influence on tourism.
- *Zambezi Delta.* The areas around the Cahora Bassa Dam and its reservoir have very limited tourism infrastructure. Plans for further expansions at Cahora Bassa North and South, as well as for the planned Mphanda Nkuwa Dam upstream of Tete, also have no immediate consequence for tourism. The two dams' flow release regimes are expected to have a strong effect on the environment, however, and therefore on the future tourism potential of the Marromeu Complex (Beilfuss and Brown 2006). The Marromeu Complex has possibly some of the best future tourism potential in the lower subbasin and in the Zambezi Delta (which is already a recognized wetland of international significance). The considerable tourism potential in these wetlands is linked to its spectacular game and bird populations. These populations have however declined in recent years for various reasons, including the reduction of natural flooding caused by the construction of Cahora Bassa Dam (Beilfuss, and Brown 2006). No final plans for operation and maintenance are yet in place to regulate flow to the benefit of the downstream ecosystems and biodiversity. It is therefore impossible at this time to assess the economic potential and the possible impact of the operation of Cahora Bassa, its planned extensions and the planned Mphanda Nkuwa Dam and reservoir.

3.4.4 Tourism – strengths and challenges

Strengths

The Zambezi River Basin is endowed with relatively unspoiled wildlife, scenic, cultural, and adventure attractions, most notably along the river and particularly at Victoria Falls, Lake Malawi/Niassa/Nyasa, Lake Kariba, Kafue Flats, Luangwa Valley, and the Zambezi Delta.

The natural game populations are one of the major tourism attractions and competitive advantages of the Zambezi River Basin. Formally protected areas, such as national parks, game reserves, conservancies, and game management areas play an important role in conserving those populations. The transfrontier conservation areas are also playing a constructive role in the further development and joint management of protected areas in the region. That area contains a number of well-developed and world-renowned tourism destinations, such as the Victoria Falls complex, the Chobe-Kasane complex, and Lake Malawi/Niassa/Nyasa as elaborated earlier. The tourism infrastructure is well established in these areas, strengthening the viability of the incomes generated as well as multiplier effect on associated businesses.

Local employment in the conservation and tourism sectors is relatively high. A large informal sector has developed around the major tourism destinations, which results in substantial local benefits for host communities. The tourism sector in the SADC region and in the Zambezi River Basin is performing well, with constant growth in tourism numbers for most areas over a number of years. With increased efforts in marketing the tourism attractions, nationally and internationally, actual arrival figures have continued to rise.

Challenges

Some of the more prominent tourist destinations are isolated. The cost of transport to those destinations is therefore high, with limited potential for tourism circuits and packages. The potential for growth in tourism is also limited by the lack of other attractions nearby which can accelerate development of tourism sites and offer a diversity of experiences. Due to the length of the Basin and issues of isolation, gateways to tourism and access to markets to support tourism are both expensive and limited. The generally poor condition of road and air infrastructure also hinders accessibility. Many areas lack bulk infrastructure support (water, electricity, and telecommunications), and will require major investment from the private sector. Lack of planning and infrastructure investment in road access to and within protected areas has also constrained private sector investment that otherwise could contributed to tourism growth.

According to tourism operators, investment in the tourism industry is limited by a number of factors. These include, the lack of favorable government policies, lengthy and complicated bureaucratic procedures for investments, lack of decentralized administrative procedures, lengthy and complex licensing processes, as well as need for developing professional capacities at multiple levels of the tourism industry. Growth has been limited to individual and ad hoc initiatives on the part of private sector investors and non-government agencies. In general, cooperation between the private sector operators and government departments is not always well organized or efficient. This limits the potential for achieving synergies and accomplishing mutually beneficial goals. The lack of cooperation also prevents the effective marketing and packaging of tourism products. Tourism information and travel distribution systems are therefore poor. Locals worry about the large percentage of tourism products owned by foreigners and the limited local benefits of tourism. Operators, on the other hand, are concerned about the lack of skilled human resources and the inability of government to facilitate a better distribution of benefits. Governments in the Basin also need to implement results-driven planning, develop relevant infrastructure, and establish incentives targeted to develop the untapped potential of priority attraction sites.

Investment for tourism projects is mostly sourced internationally rather than domestically. As a result of underdeveloped accessibility, infrastructure, and business and investment environments,

Table 3.96. Tourism – strengths and challenges

Subbasin	Strengths	Challenges
Upper Basin (from Kabompo to Cuando/Chobe, 13 to 8)	Attraction of Victoria Falls. Infrastructure and variety of products at Chobe and Victoria Falls. Private sector investment. Spin-off benefits to local entrepreneurs. KAZA TFCA initiative.	Bed night occupancies in KAZA TFCA region is very low. Lack of infrastructure in protected areas. Lack of linkages and packaging of products.
Middle Basin (from Kafue to Luangwa, 7 to 5)	Flow regulation at Kariba permitted the creation of Mana Pools, a series of ponds on the Zimbabwe bank of the Zambezi downstream. Mana Pools is a UNESCO heritage site. Biodiversity of Luangwa Valley and Kafue Flats. Low density of tourism, isolation. Traditional attraction of Kariba Dam. Unique whitewater rafting.	Limited access and infrastructure at Luangwa Valley. High cost of supplies to Luangwa and Kafue. Large fluctuation in tourism season at Luangwa Valley.
Lower Basin (from Mupata to Zambezi Delta, 4 to 1)	Unique wetland at Marromeu Complex, Marromeu Special Reserve, a buffalo reserve, two classified forests, 5% of the total of Mozambican mangrove and four hunting concessions (Ramsar site since 2003). Malawi initiative for attracting investments.	Decrease in Marromeu Complex habitats. Declined wildlife populations in Marromeu Complex. Illegal hunting and lack of management capacity at Marromeu Complex.

operational costs are high. Local entrepreneurs wanting to enter the industry or its supply chains are also hindered by the lack of financial and political support. This results in a comparatively short supply chain and a reduced multiplier effect.

Throughout the Zambezi River Basin, wildlife agencies are insufficiently funded and severely lack management capacity and other resources. As a result, infrastructure in protected areas has not been maintained and very little new infrastructure investment occurred in recent years. Most wildlife populations are not adequately surveyed and monitored and their numbers have either declined or remain low. As a result, conservation objectives and standards have not been achieved or cannot be measured. Conflicts between humans and animals are also reported in many areas. The tourism potential of the region, along with its benefits to local economies and communities, remains largely unexploited.

3.4.5 Tourism – opportunities and constraints

The growth in global and Sub-Saharan African tourism figures offers potential for expanding tourism products at well-established tourism destinations. The region is extremely well endowed with natural areas and cultural diversity, which is a growing niche market amongst international travelers. Products should be packaged to offer variety and longer visits (including cross-border excursions) to justify the high cost of tourists traveling to a distant destination.

Some areas with high tourism potential, such as Victoria Falls, already have good access infrastructure, such as airports and road linkages. These areas therefore offer an attractive opportunity to potential investors and could be expanded to be a regional and international tourism gateway. Such a transformation would require that the governments provide investors with appropriate infrastructure support and incentives. The Zambezi riparian governments recognize the economic benefit of tourism and have therefore made it a priority. Giving priority to tourism can attract international donor funding and technical support for proactive planning and development of the region's tourist potential. Public-private partnerships with nature-based concessionaires and operators within protected areas also remain an untapped source of revenue for wildlife conservation agencies and communities.

Threats to tourism development include factors such as political instability (real or perceived) in the eyes of tourists, and difficulties with accessing visas and crossing borders. Furthermore, insufficient wildlife management capacity and insufficient

Table 3.97. Tourism – opportunities and constraints

Subbasin	Opportunities	Constraints
Upper Basin (from Kabompo to Cuando/Chobe, 13 to 8)	Victoria Falls area has infrastructure and capacity for further expansion. Protected Areas have untapped potential. KAZA TFCA Initiative can access funding and draw tourists. KAZA TFCA offers opportunity for diversified products. Donor investments in Kafue National Park can stimulate private sector investment.	Over-utilization of primary tourism nodes. Increased crime at primary tourism nodes.
Middle Basin (from Kafue to Luangwa, 7 to 5)	Untapped tourism potentials Luangwa Valley and Kafue Flats.	Batoka pond could severely affect and even destroy the white water rafting operations below Victoria Falls.
Lower Basin (from Mupata to Zambezwi Delta, 4 to 1)	Substantial underutilized potential for tourism in Marromeu Complex over the long-term. Lake Malawi/Niassa/Nyasa and Shire River has untapped potential.	Flooding regime at Marromeu Complex can reduce wildlife and bird populations and tourism potential. Developments along Shire River can impact on tourism potentials.

Table 3.98. Summary of tourism arrivals in the riparian countries (World Tourism Organization 2004)

International tourist statistics	Angola	Botswana	Malawi	Mozambique	Namibia	Tanzania	Zambia	Zimbabwe
International arrivals (1, 000)	194	1,515*	471	711	986	583	515	1,854
Number of rooms	9,358	3,589*	20,871	13,807	2,749*	30,950	5,360	5,766
Nights spent by inbound tourists (1000)	143	n/a	3,617	259**	299*	2,200*	n/a	n/a
International tourist receipts ($ million)	66	468*	24	95	403	621	161	194
Receipts per international visitor	340	549	51	203	409	1,097	313	104
Source markets:*								
Africa %	21.5	88.8	76.6	87.6	75.6	44.0	71.2	77.1
Europe %	52.1	4.0	15.9	7.9	20.4	38.1	17.8	12.7
Other %	26.4	7.2	7.5	8.7	4.0	17.9	10.0	10.2

Source: WTO 2005.

Notes: n/a – No Information in report.

* 2003 – Latest figures reported; ** 2002 – Latest figures reported; *** 2000 – Latest figures reported .

Table 3.99. Economic role of tourism

	Angola	Botswana	Malawi	Namibia	Tanzania	Zambia	Zimbabwe
2008 GDP contribution ($ million)	7,656.1	1,110.0	159.0	1,051.7	1,551.8	677.2	434.8
2018 GDP contribution forecast ($ million)	13,744.6	2,458.3	270.1	2,967.9	2,693.3	1,707.3	632.3
GDP % contribution (2008)	9.9	9.4	5.9	14.5	9.7	5.1	9.8
GDP % contribution forecast (2018)	7.3	11.9	5.9	20.7	8.9	5.2	9.6
Employment (2008)	334,000	60,000	142,000	77,000	719,000	75,000	87,000
Employment forecast (2018)	333,000	80,000	178,000	129,000	829,000	92,000	93,000
Employment % (2008)	8.1	10.7	4.6	18.2	7.7	4.5	8.8
Employment % (2018)	5.9	13.2	4.6	23.7	7.0	4.5	8.7
Expected real GDP growth in 2008	13.7	1.6	4.3	5.9	3.7	6.7	–8.7
Expected real GDP average over next 10 years	4.3	6.3	4.1	7.7	3.9	6.0	3.8
2008 Export earnings from foreign tourists ($ million)	6,284.2	967.8	64.6	650.6	1,111.1	211.8	347.7
2018 Export earnings forecast ($ million)	9,413.8	2,147.2	115.8	2,092.8	1,932.2	380.0	592.9

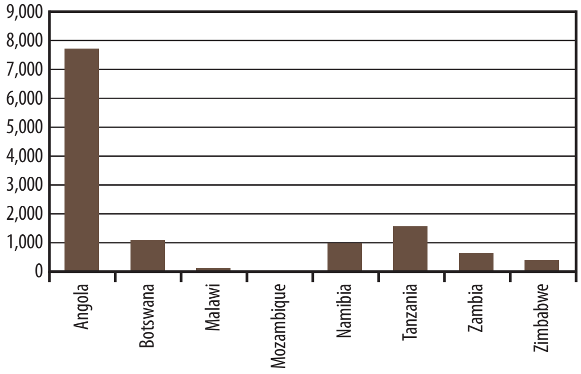
Continued on next page

Table 3.99. Economic role of tourism *(continued)*

	Angola	Botswana	Malawi	Namibia	Tanzania	Zambia	Zimbabwe
2008 Export earnings from foreign tourists (%)	10.3	12.3	9.2	15.6	31.7	4.7	16.0
2018 Export earnings forecast (%)	11.0	14.7	9.3	22.6	24.8	7.2	9.6
World Ranking – absolute size worldwide	65	118	157	122	104	131	149
World Ranking – relative contribution to national economies	79	86	147	50	82	160	81
World Ranking – long-term (10-year) growth	83	47	93	8	87	42	55

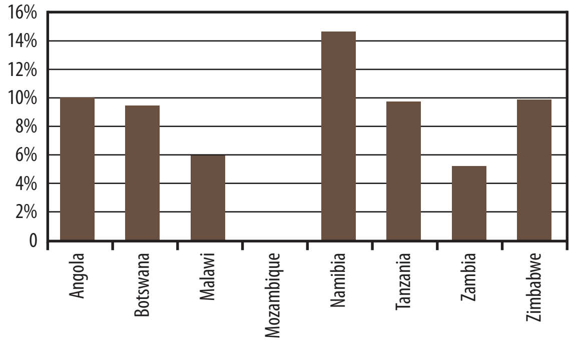
Source: WTTC 2006.
Note: Information on Mozambique was not listed in the WTTC report.

Figure 3.7. Contribution to GDP from tourism in 2008 ($)



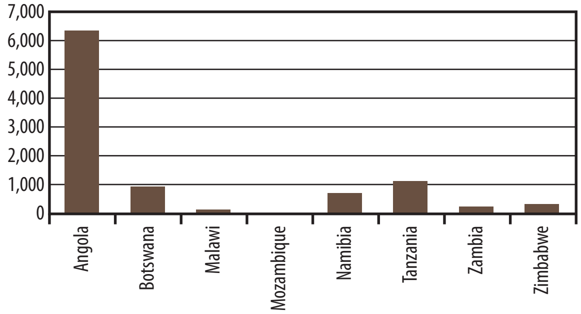
Source: WTTC 2006.

Figure 3.9. Contribution to GDP from tourism in 2008 (%)



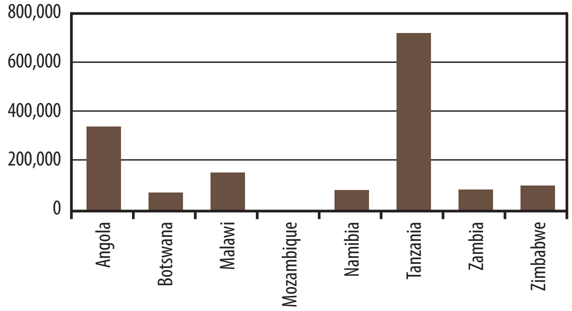
Source: WTTC 2006.

Figure 3.8. Export earnings from tourism in 2008 ($)



Source: WTTC 2006.

Figure 3.10. Employment in tourism industry in 2008



Source: WTTC 2006.

funding of protected areas has led to declining wildlife populations and reduced standards of infrastructure maintenance. This situation threatens the future the most important regional attraction for tourists.

Local communities believe that they bear a disproportionately high fraction of the cost of wildlife tourism compared to the benefits that they receive. This situation can create increased competition for land and increased wildlife-human conflict.

The change in flood regimes caused by new reservoirs could affect the scenic beauty of some river systems as well as the habitats of wildlife and birdlife, thus directly affecting primary tourist attractions. Unsustainable hunting methods can potentially also reduce wildlife populations. Uncontrolled overdevelopment could also reduce the natural attraction of prime tourist sites through landscape damage.

3.5 FISHERIES AND AQUACULTURE

3.5.1 Aquatic habitats

There are three major ichthyologic regions in the Zambezi River Basin. Waterfalls—Victoria Falls on the Zambezi River, Avumba Menda Falls on the Kafue River, and Kalomo Falls—separate the Upper Zambezi and Kafue Rivers from the lower parts of the system. There are about 85 species of fish in the upper Zambezi River and 80 in the Kafue River. The middle and lower Zambezi River Basins have fewer fish—about 60 freshwater species, plus 15 marine species in the lower river. Lake Malawi/Niassa/Nyasa is hydrologically a part of the Zambezi system, but a series of waterfalls separate its fish fauna from that of the Zambezi River System. The Lake has more endemic species than any other lake in the world. In particular, it has an extremely large and diverse fauna of cichlid fishes (more than 500 species). It has relatively few non-cichlids, which are more closely related to the Congo fauna than they are to fishes of the Zambezi River (Denconsult 1998d).

The upper Zambezi River is a “reservoir” river (Jackson 1961) which favors the evolution of fish species. Relatively high rainfall means that water is abundant all year. Extensive swamps and floodplains act as buffers to regulate the flow of the rivers, which seldom exhibit large variations in height. The floodplains have water on them for long periods of time, while the low water flow periods are relatively short. Marginal vegetation is abundant and provides cover for small fish species and juveniles of larger species.

The middle Zambezi River is a “sandbank” river (Jackson 1961) since its flow is much more variable, and it has little marginal vegetation. The lack of cover exposes small fish to severe predation. Floodplains appear again around the confluence of the Shire River and the Zambezi Delta. The number of species increases here, partly because of the appearance of marine elements but also because of the reappearance of some species typically found in the upper Zambezi.

The geology of the Basin determines the chemistry of the river, which affects the productivity of its fisheries. Much of the upper Zambezi River Basin consists of unconsolidated, wind-blown Kalahari Sands which are poor in nutrients. Kalahari sands are largely absent from the rest of the Basin, where the river and tributaries are richer in nutrients. Enriched by tributaries, the Zambezi River’s nutrient levels rise along its course.

The floodplains are widely distributed along the rivers in the upper Zambezi and Kafue river basins and, to a lesser extent, the Lower Shire and lower Zambezi rivers. They are highly productive systems, which are renewed each year during the flood season. Most fish species move onto the floodplain to breed at the time of the first floods in November and December. Spawning on the floodplain offers juvenile fish the advantages of abundant food, well-oxygenated conditions, and security from predation. Other species inhabit the system more or less permanently, living amongst the weeds in the marshes (Welcomme 1985). Economically, the most important family of the floodplains is the Cichlidae. These fish are generally sparse in the sandbank rivers of the lower and middle Zambezi.

There are only two significant natural lakes in the Basin. Lake Malawi/Niassa/Nyasa is located in the southernmost part of the Rift Valley and is very deep (with a maximum depth of 758 meters and an average depth of 426 meters) and anaerobic from about 250 meters down (Patterson and Kachinjika 1995). The second lake, Lake Malombe, has an average depth of seven meters and is essentially a southern extension of Lake Malawi/Niassa/Nyasa. It did not exist 100 years ago when the level of Lake Malawi/Niassa/Nyasa was at the lowest level known in the historical record. Its fish fauna consists of some species similar to those found in Lake Malawi/Niassa/Nyasa that have been able to pass down the Shire River. The Lake was once marshy with dense beds of aquatic vegetation and extensive reed beds around the shore. These plants

Table 3.100. Fisheries and Aquaculture – strengths and challenges

Subbasin	Strengths	Challenges
Upper Basin (from Kabompo to Cuando/Chobe, 13 to 8)	High potential with more than 300 kilometers of Zambezi River and large tributaries (Cuando/Chobe, Luanginga, Lungúe Bungo). Barotse Floodplain (average catches of 7,500 t/yr but with potential yield of 14,000 t/yr) (Denconsult 1998d). At least 60 forest lakes, mainly in the Mongu district. More than 90 species of fish. Tradition of fisheries among Lozi people. Developed commercial aquaculture, including large-scale fish farm in Kafue, small-scale fish farms in upper Zambezi, and fish farming on Lake Kariba with production estimated at 5,000 t/yr. Crocodile farms along Zambezi River, Lake Kariba and Luangwa River (Worldfish/Government of Zambia/CGIAR 2004).	Relative low productivity mainly due to nutrient-poor Kalahari sands. Low availability of data in some parts.
Middle Basin (from Kafue to Luangwa, 7 to 5)	Kafue River and floodplain, one of the most important for Zambia (average catches of 7,000 t/yr in1990–94 but with potential yield of 17,000 t/yr) (Denconsult 1998d). Lake Kariba with inshore fishery and Kapenta fishery (sardine introduced). Kapenta fishery has a potential of 40,000 t/yr. Lukanga swamps on Kafue River (average catches of 1,400 t/yr in 1966–94 but with potential yield of 8,000 t/yr (Denconsult 1998d). Presence of Lake Itezhi Tezhi (average catches of 640 t/yr in 1990–94 (Denconsult 1998d). Fishery activities are important between Kariba Dam and the Luangwa River confluence, mainly on Zambian side. Numerous small water bodies with potential catches of at least 10,000 t/yr (with average of 150 kg/ha).	Potential yield for Lake Kariba is relatively low for inshore fishery: 3,000 to 4,000 tonnes because of the steep shoreline of the lake (fish need less than 10 m in depth). Fisheries declined in 1980s in Kafue Flat after changes of water regime due to Itezhi Tezhi and Kafue Gorge dams. Few people in Lukanga Swamps now live on fishing activity. Luangwa River has a lower potential due to the seasonal variation of flow. Cyprinidae population in Zimbabwe declined after dam construction.
Lower Basin (from Mupata to Zambezi Delta, 4 to 1)	Presence of Lake Cahora Bassa, nutrient-richer than Lake Kariba with inshore fishery and Kapenta fishery. Kapenta fishery is producing 16,000 t/yr with 52 projects according (Worldfish Center 2007) and inshore fish of 6,700 t/yr (Worldfish/Government of Zambia/CGIAR 2004). Lake Malawi/Niassa/Nyasa, with diverse and complex fish fauna with average catches around 50,000 t/yr and potential estimated between 100,000 to 140,000 t/yr. The fishery sector employs more than 300,000 people in Malawi (4% of GDP). Lake Malawi/Niassa/Nyasa harbors more than 500 endemic fish species (Worldfish Center 2007). Presence of Lake Malombe with 10,000 t/yr of average catches.	Decline of tilapiine fisheries in Lake Malombe due to overfishing. Problem of eutrophication in Lake Chivero. Weak availability of data for catches on Zambezi River, especially for Zambezi Delta.

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Table 3.100. Fisheries and Aquaculture – strengths and challenges *(continued)*

Subbasin	Strengths	Challenges
Lower Basin (from Mupata to Zambezi Delta, 4 to 1) *(cont'd.)*	Presence of floodplains along the Lower Shire in Malawi such as Elephant march with 4,000 fishermen and average catches around 8,500 t/yr. Presence of numerous small water bodies mainly in Zimbabwe (around 12,000 according (Worldfish Center 2007). Fishery is possible on main part of Zambezi River from the town of Tete until the Delta with potential yield around 700 t/yr and catches estimated around 340 t/yr according (Denconsult 1998d). Fisheries in the Zambezi Delta (Beilfuss and Brown 2006EN10). Shallow-water shrimp fisheries in Sofala bank: 10,000 t/yr now with potential around 12–14,000 t/yr depending on flows in recruitment period (October to March with peak in December to January). Freshwater fisheries very important for population (more than 70 species): catfish, Mozambique tilapia, tigerfish, etc.(minimum catches estimated at 10,000 t/yr). Coastal and estuarine bottom fish (such as catfish) are sold dried in the region.	

Table 3.101. Fisheries and Aquaculture – opportunities and constraints

Subbasin	Opportunities	Constraints
Upper Basin (from Kabompo to Cuando/ Chobe, 13 to 8)	Increased demand for fish due to population growth and improvement of food regime. Potential of fish imports for most of the countries (Botswana), which can be produced in the Zambezi River Basin. Potential of the Lake Liambezi recharge project with high potential for fisheries. Dam construction create condition for fishery development in lakes. Fast rate of development of commercial fish farming in cages (Worldfish/Government of Zambia/CGIAR 2004). Dissemination and improvement of small-scale aquaculture technologies (Worldfish Center 2007). Nepad Fisheries Action Plan, the SADC Protocol on Fisheries and National Plans.	Dam construction (such as Batoka Gorge) and modified fish population (decrease of running water fish, increase of fish with more flexible breeding pattern). Pollution of Lukanga swamps on middle Kafue River due to mining activities. Increased number of fishermen in Kafue subbasin. Increased use of illegal fishing methods, mainly kutumpula and small mesh gillnets. Drought in Lukanga swamps (Worldfish/Government of Zambia/CGIAR 2004). Reduced spawning and recruitment due to severe level fluctuations in Lake Itezhi Tezhi (Worldfish/Government of Zambia/CGIAR 2004). Climate change. Invasive species such as Niloticus. Illegal fishing. Disease: epizootic ulcerative syndrome (EUS), caused by a fungal pathogen found in Zambezi River in 2007 (first time in Africa).

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Table 3.101. Fisheries and Aquaculture – opportunities and constraints *(continued)*

Subbasin	Opportunities	Constraints
Middle Basin (from Kafue to Luangwa, 7 to 5)	Very little room for expansion of Kapenta Fishery in Cahora Bassa (Worldfish Center 2007) but strong potential of development of commercial fish farming in cages. Increased demand for fish due to population growth and improvement of food regime. Potential for fish imports for most of the countries, which can be produced in the Zambezi River Basin. Dissemination and improvement of small-scale aquaculture technologies (Worldfish Center 2007). Activities of the some stakeholders (see above). Nepad Fisheries Action Plan, the SADC Protocol on Fisheries and National Plans.	Risk of overfishing in Kafue Flats. Pollution in Kafue River from the mines and towns of the Copperbelt and Lusaka Region and on Lake Kariba from Zimbabwean plateau mines. Intense development of irrigation in Zambia could increase pollution and reduce water availability. Aquatic weeds, mainly water hyacinth is largely present in Kafue Gorge, Lake Kariba.
Lower Basin (from Mupata to Zambezi Delta, 4 to 1)	Increased demand for fish due to population growth and improvement of food regime. Potential for fish imports. Dams create condition for fishery development (Mphanda Nkuwa, for example). Fast rate of development of commercial fish farming in cages (Worldfish/Government of Zambia/CGIAR 2004). Dissemination and improvement of small-scale aquaculture technologies (Worldfish Center 2007). Nepad Fisheries Action Plan, the SADC Protocol on Fisheries and National Plans. Fisheries in the Zambezi Delta (Beilfuss and Brown 2006): • Shallow-water shrimp fisheries in Sofala bank: potential around 12–14,000 t/yr depending on flows in recruitment period (October to March with peak in December-January). • Estuarine bottom fish: abundance of bottom fish is directly proportional to the extent of flooded area. • Mangrove crab.	Construction of dams (such as Mphanda Nkuwa) modifies fish population (decrease of running water fish, increase of fish with more flexible breeding pattern). Overfishing in Lake Malombe with loss of Chambo fishery. Risk of overfishing in Lake Malawi/Niassa/Nyasa. High risk of siltation in Malawi, Tete Province in Mozambique and part of Zimbabwe. Pollution downstream from Harare (Lake Chivero). Aquatic weeds, mainly water hyacinth, are largely present in Lake Chivero, Lake Cahora Bassa, the Lower Shire River, the Lilongwe River. Pollution of floodplains. Water level fluctuation in Delta. Reduction of natural floods in Delta.

have now been eliminated by the intensive use of seine nets.

Two major reservoirs have been constructed on the Zambezi River: the first, filling of Lake Kariba (around 5,400 km^2) was completed in 1968 and the second, Lake Cahora Bassa (around 2,700 km^2), was completed in 1975. Other important reservoirs include Lake Itezhi Tezhi and Kafue Gorge Upper reservoir on the Kafue; Mulungushi and Mita Hills on tributaries of the Luangwa; Lakes Chivero and Manyame on the Manyame River; and the Sebakwe dam on the Sebakwe River.

There are numerous smaller bodies of water throughout the basin. Most are reservoirs that have been constructed during the last hundred years. Reservoir construction has been most intense in Zimbabwe, where there are now about 4,500 reservoirs with individual surface area greater than one hectare. These small bodies of water have significant potential as sources of fish that has not been fully realized. Most small reservoirs are not built to be fisheries, however, which may restrict their productivity. For example, they typically fluctuate much more than natural lakes do, especially when they are used for irrigation. Farmers use much of the water, and many small reservoirs are almost completely emptied each year. The effects of these fluctuations on fish production have not been studied.

The only estuaries in the Zambezi River Basin are found in the Zambezi Delta. Their salinity ranges from fresh water in their upper reaches to seawater at their outer reaches. Salinity can vary daily along this gradient according to the tides or seasonally according to the flow of the rivers. With reduced freshwater inflow, salinity can rise above that of seawater. Estuarine fish are able to tolerate a wide range of salinity. Some freshwater species, like the Mozambique tilapia (*Oreochromis mossambicus*) can also penetrate estuaries. Many typically marine estuarine species—like gobies, mullets, and tarpon—can also tolerate freshwater and can be found far inland. The Bull Shark, for example, (*Carcharhinus leucas*) has penetrated the Zambezi River as far as Cahora Bassa (Skelton 1993).

Temporary waters can be found throughout the Basin during the rainy season and include the "forest lakes" of the Upper Zambezi and the "pans" of the Middle and Lower Zambezi. Few have significant importance for fish production. The lungfish (*Protopterus annectens*) is an important inhabitant of many temporary waters in the lower Zambezi and are utilized by local people. Man-made habitats like sewage ponds, drainage ditches, and water storage dams can also be found throughout the Basin. Many of them support fish, but their potential as a resource has never been fully investigated. Strengths and challenges in fisheries is summarized in table 3.100., and opportunities and threats in table 3.101.

3.6 NAVIGATION

Navigation on the Zambezi River (figure 3.11.) comprises three major categories: main international transport routes (Kazungula, Luangwa-Kanyemba); major national routes, such as those in the upper Zambezi River and on Lake Malawi/Niassa/Nyasa; and small crossings that provide access to major markets (Denconsult 1998c). Navigation on the tributaries consists mostly of ferry-pontoons for vehicles and cargo. There are major crossings at the following tributaries: Kabompo River, Kafue River, Chobe River (Namibia and Botswana), and Shire River (Mozambique and Malawi). All three countries bordering Lake Malawi/Niassa/Nyasa utilize the lake for navigation (Denconsult 1998c). The terminal section of the Zambezi—running from the Indian Ocean and 570 km upstream from Mphanda Nkuwa—is the longest navigable portion of the River. Coal was transported over the river in barges in the 1940s and molasses in the 1970s. Construction materials for the Cahora Bassa Dam were also transported in barges up Mphanda Nkuwa. At present, navigation only occurs at the crossings at Luangwa/Kanyemba and Caia (where construction of a new bridge started in 2009).

Other projects in the region may also require navigation. There are plans for coal mining activities in the Tete province, which will involve transportation of coal in barges down the Zambezi River. The rehabilitation of Sena Sugar Estates may create the need for navigation for transporting molasses. Finally, the construction of the Mphanda Nkuwa river Dam will make the portion of the river between Mphanda Nkuwa and Cahora Bassa navigable (SADC 2000a). The navigation potential of the Shire River depends not only on water flows from the Lake Malawi/Niassa/Nyasa, but even more on water weeds, which present a major obstacle. Major navigation between Nsanje/Chiromo (Malawi) and Chinde might also resume (SADC 2000a).

Compared to Lake Kariba, which lies further upstream in the central Zambezi River system, the development of navigation on Lake Cahora Bassa has been slow for two main reasons. First, the lake is situated in a more remote area far from major towns and from the capital Maputo in particular. Second, development in Mozambique was significantly hampered by the civil war which ended in 1992. Lake Cahora Bassa was frequently used for navigation soon after impoundment and there were even plans for expanding navigation efficiency. Today transfer service is offered between Songo and Gumbo (SADC 2000a). Some 30 km before the reservoir starts, the Cahora Bassa Gorge is characterized by very high slope margins, ploughed by small gulfs. Although Lake Cahora Bassa lies along the reservoir center line and is sufficiently deep for navigation, it does present some obstacles such as rock bottom is at Nhacapiriri, while sand bottom is reported specially at Zumbo and Mucanha. Within

Lake Cahora Bassa, half submerged trees are still a serious hazard in shallow areas and in the entrance channel (SADC 2000a).

3.6.1 Ongoing initiatives

NEPAD's development of the Shire-Zambezi Waterways Project is among the main navigational initiatives in the region. The project will entail reopening of the Shire and Zambezi rivers to navigation to provide a direct waterway transport system between Nsanje in Malawi and the port of Chinde on the Indian Ocean—a distance of approximately 238 km. In addition, the project will link Malawi to the region as a whole (SADC 2000b). In April 2007, the governments of Malawi, Mozambique, and Zambia signed a MoU for collaboration on the implementation of the Shire-Zambezi Development Project (Malawi/Mozambique/Zambia 2007).

The project will include the following major components:

- Construction of the port of Nsanje in Malawi and expansion and modernization of the port of Chinde in Mozambique. (Hydroplan 2006);
- Dredging and conversion of the Shire-Zambezi waterway into a modern canal;
- Construction of Chiromo Rail/Road Bridge;
- Rehabilitation and upgrading of railway line from Nsanje through Blantyre, Lilongwe, and Mchinji to Chipata near the Zambia/Mozambique border;
- Provision of barges on Lake Malawi/Niassa/Nyasa to serve Malawi, Mozambique and Tanzania;
- Construction and rehabilitation of the road from Salima through Lilongwe and Mchinji to Zambia;

Table 3.102. Navigation – strengths and challenges

Subbasin	Strengths	Challenges
Upper Basin (from Kabompo to Cuando/Chobe, 13 to 8)	Existence of ferry crossings in Chavuma, Zambezi town, Katima Mulilo, Kalongola Senanga, Kazungula. Since 2004, new bridge on Katima Mulilo. Tourism activity is developed on Zambezi and Chobe rivers.	The crossings upstream had to stop operation during 2 to 3 months during period of low water level. Kazungula crossing is operating all year but with problems of shallow water at the landing site. Lack of bathymetric data and depths profiles.
Middle Basin (from Kafue to Luangwa, 7 to 5)	Navigation on Lake Kariba is developed both for Zambia and Zimbabwe.	Low water level during drought period has created problems with too shallow water at the shore line mainly on Zimbabwean side of Lake Kariba. Lack of bathymetric data and depths profiles.
Lower Basin (from Mupata to Zambezi Delta, 4 to 1)	Navigation in Lake Cahora Bassa is increasing. A recent ferry crossing was put into operation between Luangwa (Zambia) and Kanyemba (Zimbabwe). Navigation on Lake Malawi/Niassa/Nyasa has long tradition and involves several countries (Tanzania, Malawi and Mozambique). Section downstream Mphanda Nkuwa site is navigable until Chinde on the Indian Ocean.	Section between Lupata Gorge to Mutarara is most critical, with strong current between Lupata and Chiramba. Upper Shire upstream Liwonde reservoir has natural barriers of sand banks. Rapids are present in the central Shire River from Matopo Bridge to Muchirson. Navigation in Lower Shire is affected by low water level, lack of dredging and presence of water weeds. Navigation on Zambezi River downstream of Cahora Bassa depends of high flows with potential competitive use with other sector. Use of port of Chinde has been restricted due to changes of tracks and depths of the entrance channels. Lack of bathymetric data and depths profiles.

- Construction and rehabilitation of the road from Nkhatabay through Mzimba into Zambia, Rwanda, and Burundi; and
- Construction of the road from Nsanje to Chiromo and Thyolo.

The following benefits are projected:

- Provide Malawi and Zambia—otherwise landlocked countries—with direct access to the sea and global economy;
- Reduce costs of goods and services for landlocked countries like Malawi and Zambia—by at least 60 percent based on preliminary estimates; and
- Contribute to the NEPAD objective on infrastructure development as a pillar for accelerating economic growth and poverty reduction in Africa.

Other recent or ongoing initiatives have improved the conditions of transportation in the Zambezi River Basin, including:

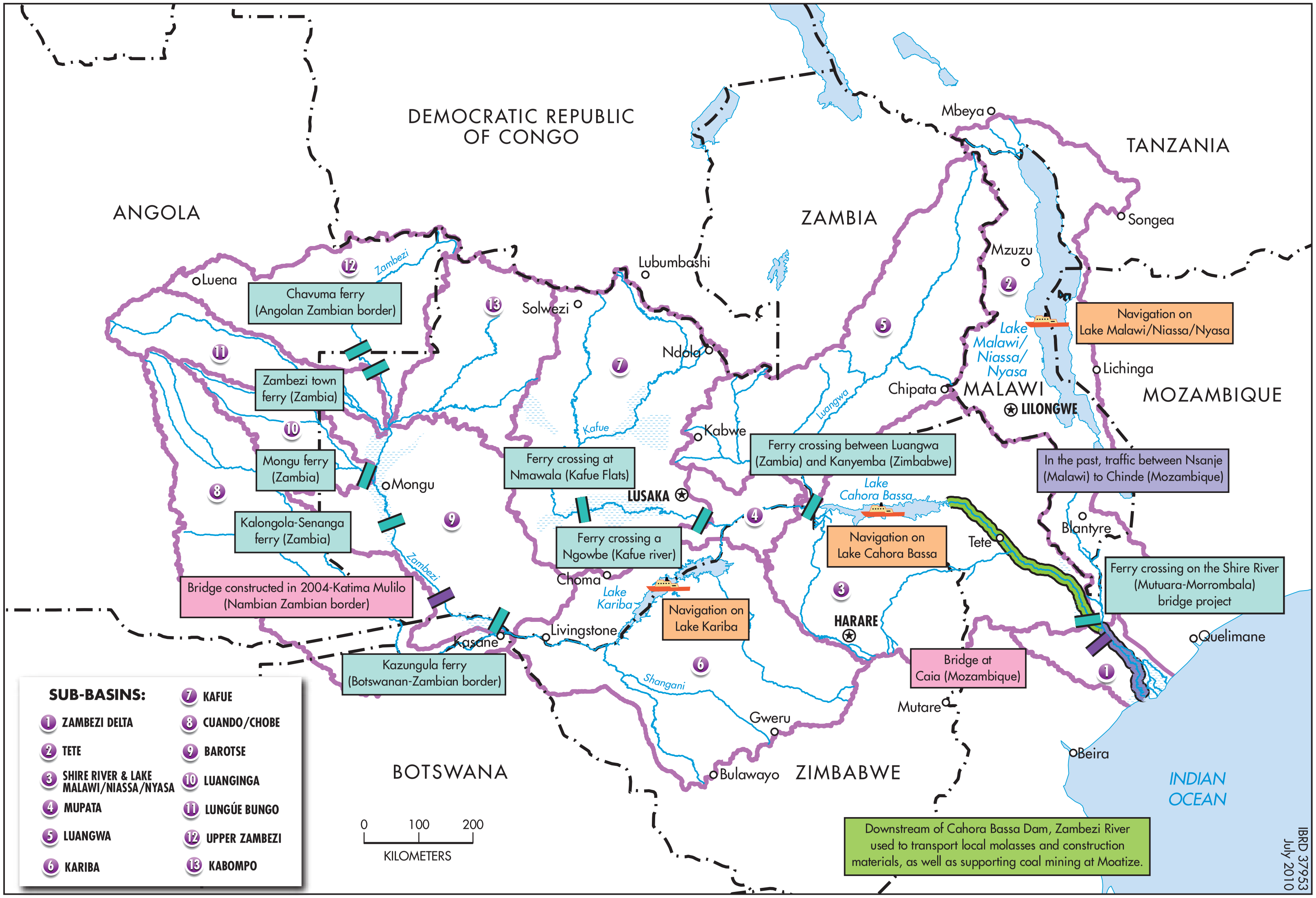
- Construction of the Caia bridge (Mozambique) which will replace ferry transport;
- Construction of the Katima Mulilo bridge (built in 2004);
- Creation of ferry crossing between Luangwa and Kanyemba; and
- A second bridge in Tete.

In 2004, the Brazilian company CVRD was granted the concession of the Moatize coal mine for 25 years. Eighty percent of the production is aimed for export as coke coal and a thermal power plant between 750–1,500 MW is to be constructed, with a 120 km transmission line between Matambo and Songo. Among other investment in the mine, the company envisages the construction of a port terminal and a new section of railroad. Development of navigation is also an alternative to the railroad, which will not be sufficient to absorb all coal production.

Table 3.103. Navigation – opportunities and constraints

Subbasin	Opportunities	Constraints
Upper Basin (from Kabompo to Cuando/ Chobe, 13 to 8)	Trade along the north south routes is increasing in the region and used ferries crossings, especially for international borders (Katima Mulilo between Namibia and Zambia, Kazungura).	Increase of water abstraction upstream that will reduce flow water level.
Middle Basin (from Kafue to Luangwa, 7 to 5)	Regular commercial navigation on Lake Kariba is servicing small communities in Zambia and Zimbabwe. Opportunity of tourism development on Lake Kariba.	Increase of water abstraction upstream that will reduce flow water level.
Lower Basin (from Mupata to Zambezi Delta, 4 to 1)	Trade along the north south routes is increasing in the region as is the use of ferries crossings, especially at international borders (Luangwa-Zambia/Kanyemba-Zimbabwe). Opportunity of tourism development on Lake Cahora Bassa. Presence of Sena Sugar State Company that had a fluvial fleet in the past. Existence of NEPAD's initiative: "Shire-Zambezi Waterways development Project" between Nsanje (Malawi) and Chinde (Zambezi delta in Mozambique). Caia Bridge is being constructed across Zambezi river may replace ferry crossings. It is expected that the railroad to be constructed by CVRD (coal mine in Moatize) will not be capable to absorb all the coal production and developing the navigation is an alternative.	Navigation on Lake Malawi/Niassa/Nyasa, though earlier well developed has been declining due to improvement of road and low water level. Water weeds are drained into the Zambezi from the Shire River. Navigation on Shire-Zambezi River suffers from concurrence with other transport (railways), especially with the rehabilitation of the Sena railway line and the arrival of its Malawi extension in Nsanje. Changes of geomorphological conditions of the river. Increase of water abstraction upstream that will reduce flow water level. Reduction of water releases in dry season.

Figure 3.11. Navigation in the Zambezi River Basin



Source: Conservation International 2008.

3.7 MUNICIPAL AND INDUSTRIAL WATER SUPPLY

3.7.1 Domestic water use

A portion of the water used by domestic and urban users in the Zambezi River Basin is derived from groundwater sources. Because groundwater is not overused at basin level, it does not have a significant direct impact on the Zambezi Watercourse and its tributaries. Since reliable data on domestic and institutional water use is not readily available from most urban centers in the Zambezi River Basin, water use figures had to be estimated and modeled (which also provides estimates for effluent generation). The following assumptions had to be made: current net urban water use (taking into account return flows and water use by service businesses) is 85 liters per day per capita; per capita rural water use is 20 liters per day; and surface water provides 90 percent of the urban water supply and 15 percent of the rural water supply. Based on these assumptions and 2005–2006 population data, urban water use was estimated to be 175 million m^3 per year and rural water use was estimated to be 24 million m^3 per year.

3.7.2 Industrial and mining water use

A number of urban centers in the Zambezi River Basin have significant industrial and commercial activity other than mining (Euroconsult Mott MacDonald 2007). Particular urban areas with high concentration of industrial activity include Kitwe, Ndola, Lusaka, and Kafue in Zambia; and Bulawayo, Gweru, Kwe Kwe, Harare in Zimbabwe (table 3.105.). There is very little reliable data for water use and wastewater discharges from these industries and their water use is therefore estimated using the following information, estimates, and assumptions:

Table 3.105. Industrial water use by main urban areas (m^3/day)

Total industrial water supply	98,615
Net industrial water use	68,182

- A list of industries for each town (see for more details Euroconsult Mott MacDonald 2007);
- Particular attention is given to industries that use comparatively more water than others ('wet industries');
- Industrial water demand in each town is estimated as a percentage of total demand of all urban water users;
- Losses due to abstraction, treatment, and reticulation are estimated at 30 percent;
- Losses from the sewers are estimated at 10 percent; and
- Estimates were made to account for the fraction of wastewater returned to the watercourse after losses in treatment and irrigation of final effluent and the fraction discharged to open drains.

Based on these estimates, net industrial water use is less than 70,000 m^3 per day (25 million m^3 per year). This is rather insignificant compared to total water supply. A major portion of the used industrial water is returned to the watercourse as treated wastewater.

Table 3.104. Rural and urban water use (2005–2006)

	Population 2005/2006	Per capita consumption/ day (liters)	Surface water (%)	Total consumption (million m^3)
Urban	7,602,200	70	90	175
Rural	22,366,800	20	15	24

Source: Euroconsult Mott MacDonald 2007.

3.7.3 Identified projects of interest

Botswana: the Chobe-Zambezi Water Transfer Scheme

Rapid growth has led to rising water demand in the main population centers throughout Botswana, in particular the greater Gaborone area. The government—through the Ministry of Minerals Energy and Water Resources (MMEWR), Department of Water Affairs (DWA)—therefore commissioned a study to investigate the feasibility of water abstraction from the Chobe-Zambezi River system near Kazungula/Kasane Area in Chobe District (WRC 2009). Via a pipeline, the water would be moved to the Dikgatlhong reservoir. An estimated 800 million m^3 per year of water will be made available to meet the domestic, industrial, mining, and agricultural water demands within Botswana by 2020.

The review of Botswana National Water Master Plan recommended commissioning of the Chobe-Zambezi Transfer Scheme by 2022 (SMEC and EHES 2006). Botswana currently requires about 500 million m^3 per year (20 m^3 per second) from the Zambezi River for agricultural purposes, mainly for the Zambezi Integrated Agro-Commercial Development Project. Given the deficit of water in urban centers, however, Botswana water requirements will increase drastically. To meet that need, Botswana would require implementation of the Chobe-Zambezi Water Transfer Scheme between 2011 and 2020. The proposed water transfer scheme is expected to link up with the existing North-South Carrier Water Project (WRC 2009).

Zambia: water transfer and abstractions

There is a proposal to withdraw an additional 500,000 m^3 per day (six m^3 per second) from the Kafue River through a pipeline to supply water to Lusaka (Republic of Zambia 2008). Water withdrawal from Lake Kariba for the Maamba Colliery coal mine in southern Zambia is also under consideration. The recently completed power generation planning exercise also includes a proposal to extend mining operations to feed a 200 MW coal-fired thermal plant (Chubu Electric Power Co. Ltd. 2009). Water consumption of the mining operation and power plant cooling is estimated at 100 liters per second.

Other mining projects have been identified in Zambia, but their studies are not sufficiently advanced to include estimates of water consumption. Those projects include:

- Because mining activity in the Copperbelt fluctuates with global metal prices, so will the water abstraction or mine dewatering for mines.
- The Kangaluwi Copper/Gold Project, located inside the Lower Zambezi National Park. It is believed to be a potentially "world class open pit copper deposit" and is the site of rapidly expanding exploration, including a major resource drill out project during 2008 and 2009.
- The Cheowa Copper/Gold Project, located in the Chiawa Game Management Area (GMA). This is a joint venture with Glencore International (now combined with the Chongwe Copperbelt Project. The Chumbwe and Mpande areas, also located in the Chiawa GMA, are included in a Uranium Joint Venture with Lithic Metals and Energy, along with Mulungushi and Rufunsa licenses.
- The Mulofwe Project is located in the river catchment above the Chiawa GMA and LZNP. This is a Uranium Joint Venture with Rio Tinto Zinc.
- A mining operation in Siavonga in the catchment directly above Lake Kariba.

Zimbabwe: water transfer and abstractions

Abstractions from Lake Kariba include cooling water for the planned 1,400 MW Gokwe coal-fired power plant in Zimbabwe whose water consumption (including that for coal processing) is estimated at 18 m^3 per second.

The city of Bulawayo in southern Zimbabwe is supplied by a dam on the Munyati River near its confluence with the Sanyati River. In dry years, however, storage in the dam is insufficient to satisfy demand from Bulawayo. A project has therefore been proposed to pump water from Lake Kariba into the dam to supplement the withdrawal deficit. A feasibility study for this project was completed in 1996 (SWECO 1996).

Mozambique: Moatize and Benga coal mines and coal-fired thermal power plants

According to consultation with GPZ and ARA-Sul in November 2008, the Moatize coal mine is planning water abstraction of between nine and 18 m^3 per second from the Zambezi River. The Brazilian company Vale was granted the concession of Moatize coal mine in 2004 for a period of 25 years. The mine should enter production 2010. The project also includes a thermal power plant with an installed capacity of 2,400 MW and a 120 km transmission line between Matambo and Songo. The estimated water consumption of the mine and the power plant is 1.4 m^3 per second, which suggests that most of the planned water abstraction will be used for plant cooling of which most returns to the river. The company also envisages the construction of a port terminal and a new section of railroad. It is expected that the railroad will not be capable of absorbing all the coal production.

Riversdale Mining, an Australian company associated with TATA, is also preparing investment in the Benga coal mine and a 2,000 MW coal-fired thermoelectric power plant. Overall water consumption of the project is estimated at 1.1 m^3 per second.

3.8 WATER QUALITY

Across the Zambezi River Basin, understanding and protecting the quality of water is crucial for its different uses and in planning water resources projects—whether it is for drinking water, industrial use, irrigation purposes or for sustaining diverse and irreplaceable ecosystems. Water quality problems range in magnitude, form and source in the ZRB. The major sources of pollution include contamination from domestic waste, agriculture, the mining sector, and industries. Degraded water quality has widespread economic and environmental impacts, and often poses a direct threat to human and animal health if not managed.

3.8.1 Pollution from domestic waste

Pollution from domestic waste results from the disposal of sewage, whether treated or not, into river or streams. While most of the cities in the Zambezi River Basin have sewage treatment works, they are not technically advanced, and there is great need for improvement and upgrading. Water treatment in the city of Lusaka, with a population in excess of one million, is a serious concern. There are no sewage treatment facilities and waste is discharged into the Kafue River. Other significant towns without treatment facilities include Kafue and Livingstone. Very few of the small towns and villages have treatment facilities.

Untreated domestic sewage primarily causes problems such as eutrophication. The nutrient load (nitrates and phosphates) increases and remains very high, negatively affecting the balance of phytoplankton assemblages among others. Certain algae and vegetation such as hyacinth grow disproportionally in size and magnitude which in turn, contributes to a reduction in oxygen levels. Furthermore, the organic content of sewage is broken down by bacteria, a process which also depletes oxygen. With lower levels of oxygen and unhealthy phytoplankton assemblages, whole aquatic food chains and interdependent ecosystems deteriorate. Although eutrophication is not a direct health hazard to humans (but occasionally for some livestock) it also becomes a nuisance. Overgrowth of algae can clog water distribution systems used for irrigation while hyacinth present on Lake Kariba for example, can be detrimental to fishing and tourism. Some algae can lead to bad tastes and odors in water and removing these is very costly. There is no evidence that nutrient pollution has reached problematic levels in the Zambezi River Basin on the whole and the problems tend to be geographically limited to particular areas.

One of the most serious implications of untreated domestic sewage in the region is the risk of waterborne disease such as cholera and typhoid. Across Sub-Saharan Africa, under five mortality rate is 144 per every 1,000 births (compared to eight in every thousand in the USA). Twenty percent of these deaths are attributed to diarrhea caused by waterborne diseases. An important intervention is to disinfect effluents discharged into rivers, but this does not appear to be done in the Basin. An indicator of contamination is the presence of *e. coli* bacteria. Provided the *e. coli* count is within the WHO (World Health Organization) guideline limits, the risk of disease is minimal. While it is clear that sanitation, sewage treatment, and the disposal of effluent is far from adequate in the Zambezi River Basin, there is little evidence that this is causing waterborne disease at basin level. This is most likely because the high flow levels, in most tributaries in the Basin, adequately dilutes the effluent. Developments that decrease dilution, especially consumptive use such as irrigation, will decrease this process of dilution and hence increase the risk of waterborne disease. This needs to be accounted for when considering irrigation development options.

A general indication of domestic waste issues can be obtained from population estimates and distributions in the Basin. According to Euroconsult Mott MacDonald (2007) the population in the Basin amounts to approximately 30 million and the estimated water use as 199 million m^3 per year. Table 3.106. lists the major urban cities and towns in the Zambezi River Basin together with the size of estimated population, totaling approximately 7.6 million.

The Sector Study Report of 1998 (Denconsult 1998e) estimates water supplied to those cities at 217 million m^3 per year, of which approximately 39 percent is delivered to treatment plants. Of the sewage treated, approximately 78 percent is discharged into watercourses. In other words, an estimated 66 million m^3 is discharged into watercourses annually. This needs to be seen in the context of the flow in the Zambezi River, which is estimated at 107 billion m^3 in total.

According to earlier publications (Denconsult 1998e), the cities of Bulawayo and Harare are described as having adequate treatment plants and that effluent discharged from Bulawayo into the Gwayi River and from Harare into the Manyame River are of adequate standards. However, more recent reports (Nyamangara and others 2008) indicate that due to the economic collapse of Zimbabwe, the sewage treatment plants are not always operational resulting in untreated or partially treated sewage being discharged directly into the watercourses in Harare. In addition, small industries are discharging industrial effluent into rivers since the fines imposed are less than the cost of treating the effluent. The water in the streams is concurrently used for irrigating the crops cultivated alongside these rivers. This has resulted in problems such as cultivation of lettuce which is known to accumulate heavy metals, posing a serious health risk for Zimbabweans who rely on locally produced fresh produce.

Table 3.106. Urban cities and towns in the Zambezi River Basin

Country	Subbasin	Urban center	Population
Zambia	Kafue (7)	Chingola	164,600
		Chililabombwe	60,900
		Mufulira	136,600
		Kitwe	406,100
		Luangshya	129,100
		Ndola	418,400
		Lusaka	1,211,100
		Kafue	51,200
	Kariba (6)	Livingstone	108,900
	Luangwa (5)	Chipata	81,600
		Kabwe	197,400
Zimbabwe	Kariba (6)	Hwange	58,700
		Bulawayo	1,003,700
		Gweru	157,500
		Kwe Kwe	81,500
		Kadoma	110,300
		Chegutu	40,200
Malawi	Shire River and Lake Malawi/ Niassa/Nyasa (3)	Lilongwe	521,800
		Blantyre	562,400
Zimbabwe	Tete (2)	Harare	1,976,400
Mozambique	Tete (2)	Tete	123,800
Total			**7,602,200**

Source: Euroconsult Mott MacDonald 2007.

3.8.2 Pollution from the agriculture sector

An estimated 5.2 million hectares of the Zambezi River Basin is cultivated for agriculture (irrigated and dry-land), of which about 80 percent lie within Malawi, Mozambique, Zambia, and Zimbabwe. The majority of cultivated crops is made up of maize, cotton, cassava, oil seeds, and sugar cane. Much of the agriculture takes place at a subsistence level where the use of fertilizers is limited.

Pollution from agriculture is due mostly to unsuitable application of fertilizers. During rainfall, some of the fertilizer can be washed out into streams and rivers. Also, where crops are irrigated, over-irrigation or over-application of fertilizer can result in the fertilizer leaching out of the soil and entering rivers and streams with the base-flow. Inefficient irrigation practices, such as flood irrigation, also contribute significantly to pollution from agriculture. Fertilizers are essentially nutrients (phosphates and nitrates), which will contribute to the eutrophication processes.

In addition to fertilizers, insecticide and herbicide applied to crops can also be a source of pollution. Modern insecticides and herbicides can break down very rapidly on contact with water.

3.8.3 Pollution from the mining sector

The pollution from mines is highly variable and depends not only on the type of mineral being mined but also the type of mining practiced. Surface mining, such as strip mining or open cast mining, can have a big impact if rainfall is allowed to drain from these areas into rivers. Deep mining creates water quality problems through dewatering. The water pumped out of the mine is often contaminated with blasting debris. Heavy metals and other compounds of the oxidation process are of great concern. This is often referred to acid mine drainage (AMD) and occurs when there are sulfites in the rock being mined. Contact with oxygen and water form sulfuric acid, which then dissolves a range of metals out of the rock. Toxic metals such as lead, mercury, and arsenic are found in AMD. Unless treated properly before being discharged into the river, this can have a long-term detrimental effect on the environment and human health. Deep mining activities in the Zambezi River Basin include the extraction of gold, platinum, chrome, and copper. AMD is associated with all these types of mining.

Water quality is an increasing concern, particularly in the Kafue River Basin. The river also provides domestic water supply to over 40 percent of the Zambian population. In Zambia's Copperbelt Province lies the mineral rich area the Copperbelt, of which much falls within the Kafue River Basin. Heavy metals such as copper, manganese, and lead

Table 3.107. Water quality in the Kafue River Catchment

		Average value					
		Surface water		Groundwater			
Parameters	ECZ Regulation Limits	Kafue River	Discharge	Nakambala Estate	Kafue Fish Farm	Kafue Sewage	Nitrogen chemicals
Temperature (°C)	40	23.40	23.40	25.50	23.90	25.10	25.60
pH	6–9	7.12	7.71	7.11	7.00	6.69	6.80
Conductivity (µS)	4,300	225.00	485.00	1,613.00	2,109.00	595.00	1,791.00
D.O (mg/l)	5	2.32	3.90	1.52	1.60	0.75	1.30
Ammonia (mg/l)	10	0.31	0.61	0.50	1.60	0.27	0.50
Nitrates (mg/l)	50	11.10	36.00	51.00	73.80	15.60	30.20
Phosphorus (mg/l)	1	0.33	1.64	1.40	2.07	1.84	2.12
Potassium (mg/l)	NR	2.97	18.60	20.00	17.60	14.90	19.20
Calcium (mg/l)	NR	28.90	56.90	166.00	121.00	37.30	105.00
Magnesium (mg/l)	500	13.10	26.90	88.80	79.00	46.90	79.80
Iron (mg/l)	2	0.22	0.61	n/a	n/a	n/a	n/a
COD (mg/l)	90	75.00	137.00	113.00	1,043.00	86.00	110.00
BOD (mg/l)	50	10.00	51.00	14.00	150.00	16.00	28.00

Source: Environmental Council of Zambia 2000.
NR = No ECZ Regulations; n/a = Not analyzed.

have been detected in many rivers and streams, in particularly the Kafue River and its tributaries. Within the region, the area occupied by tailings dams, waste rock dumps, and highly contaminated soils has been estimated at 78 km^2. New mines and those older ones still operating, along with their associated metallurgical treatment plants and smelters, continue to add their wastes to the surface environment. Mining-related and industrial contamination of surface waters results from four processes: washout of fine particles from dumps and ore processing plants; overflow of water from tailing facilities; seepage of water through tailings dams, and/or outflow as a result of embankment failure; and the drainage of process waters from smelters and acid plants, both systematically and through equipment failure or mismanagement of operation.

Despite the concerns regarding possible heavy metal pollution from Copperbelt mines, until recently there has been little data to suggest that this is in fact a problem. This is because the environmental degradation was poorly quantified in spatial term since the availability of accurate and up-to-date regional geochemical data for both unpolluted and polluted areas has been limited. This deficiency has been remedied recently by a comprehensive investigation of geochemical data and the extent of industrial pollution in the Central-Northern part of the Copperbelt province of Zambia (the area where most mines are located around Kitwe, Kalulushi, Chambishi, Chingola, Mufulira, and Chililabombwe) and by the publication of an environmental and geochemical atlas of the study area in 2007 (Kříbek, Majer, and Nyambe 2007). The atlas presents a series of maps for the study area that include:

- Concentrations of total sulphur, arsenic, cobalt, copper, mercury, lead, zinc, chromium, nickel, and vanadium in surface and sub-surface soils;
- Coefficients of industrial pollution in surface soils;
- Trace metals in agricultural plants; and
- Coefficient of industrial pollution of stream sediments.

The main sources of anthropogenic contamination in the soils and plants are:

- Gaseous and solid emissions from smelters;
- Dust from dry parts of tailing impoundments; and
- Dust from mining operation, processing plants, and slag deposits.

The main sources of pollution in streams are:

- Industrial water discharged into the watercourse;
- Seepage and overflow from tailing impoundments; and
- Erosion and washout of fine-grained particles from spoil banks and tailing impoundments (siltation).

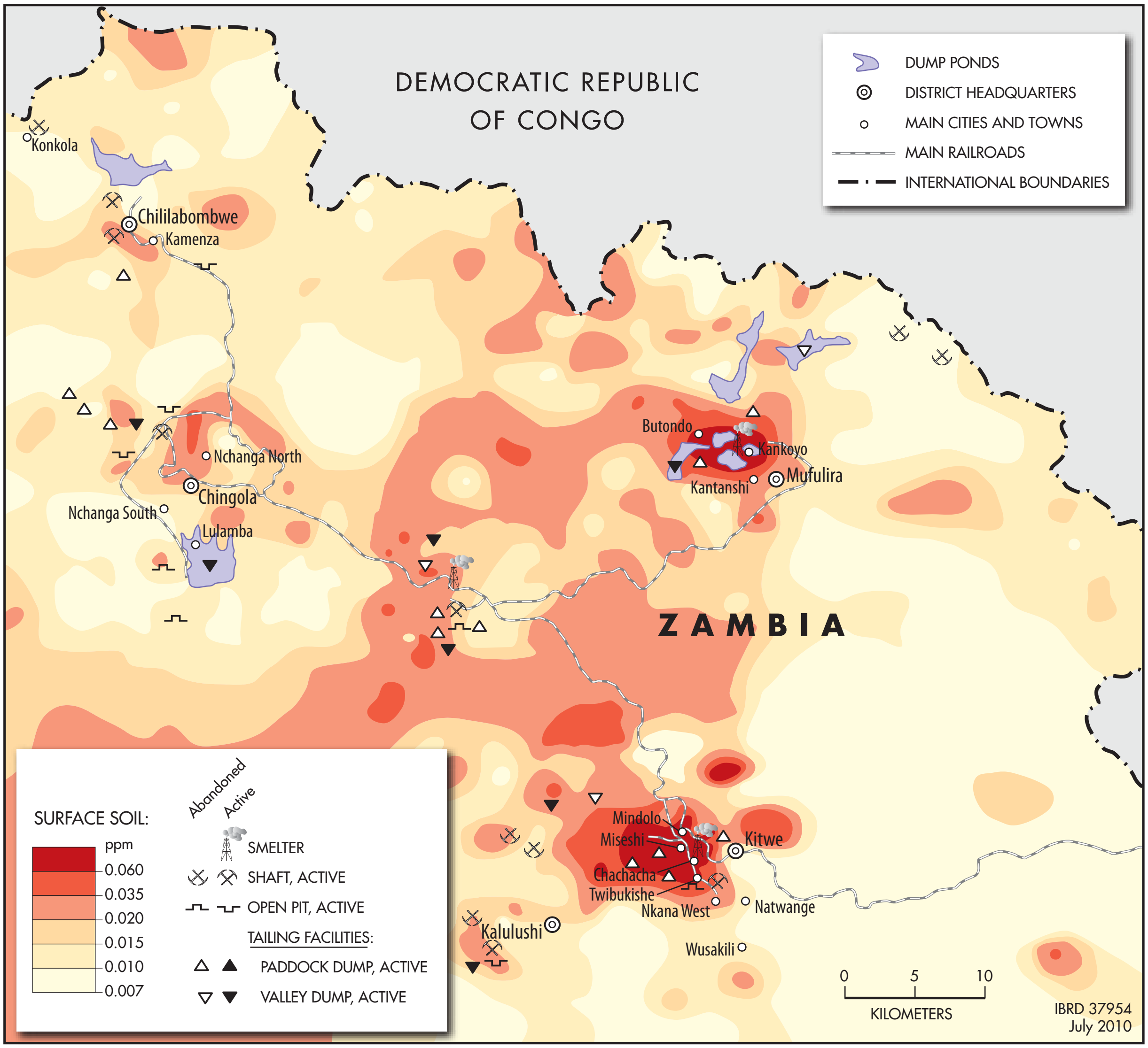
Figure 3.12. is a map of mercury contamination in the central and northern parts of the Copperbelt Province. As shown on the map, concentrations above 0.06 parts per million are not uncommon.

Results of the environmental and geochemical mapping of the study area are presented in table 3.108.

Several concentrations exceed the national limits. The main conclusions of the investigation by Kříbek *et al.* (2007) are that:

- Main sources of contamination of terrestrial systems (soils and vegetation) are ascribed to dust fallout from smelters, crushers, and dry beaches of tailing impoundments.
- Contamination of surface waters and stream sediments is ascribed to siltation that results from washout of fine particles from dumps and ore-processing plants, overflow from tailing facilities, leakage of water through the tailing facilities, and the drainage of technological water from smelters and acid plants.
- Concentrations of Arsenic (As), Cobalt (Co), Copper (Cu), Mercury element (Hg), Lead (Pb), Zinc (Zn), Sulfur (S) and Selenium (Se) in surface soils are usually higher when compared with subsurface soils. These elements reflect an extent of industrial contamination.
- Contents of heavy metals in agricultural plants depend on anthropogenic contamination and bedrock geochemistry. In less contaminated areas, cassava and sweet potato leaves are contaminated. In heavily contaminated areas, heavy metal concentrations also increase in roots.

Figure 3.12. Mercury concentrations in central and north Copperbelt



Source: Kribek, B., V. Majer, and I. Nyambe 2007.

Table 3.108. Contamination in the Copperbelt

	pH	Al	Ca	Cd	Co	Cu	Mn	Ni	Pb	SO_4	Se	U	Zn
		ppb	ppm	ppb	ppb	ppb	ppb	ppb	ppb	ppm	ppb	ppb	ppb
EU limit	6–8	1,500	250	1	10	30	500	50	15	300	5	50	200
Zambia limit	6–9	2,500		500	1,000	1,500	1,000	500	500	1,500	20		10,000
Chambeshi	3.62	6,929	709	2.06	29,528	16,442	8,673	1,776	317	2,617	37.8	99	1,741
Busakile	2.04	2,115	197	7.02	909	7,405	466	51.5	161	1,396	13.0	5.25	346
Copperbelt Uncontaminated	7.04	25.4	27.5	<0.04	1.4	7.5	28.1	0.64	1.19	4	<0.5	<0.02	12.9

Source: Environmental-Geochemical Mapping Surface Water Chemistry Central-Northern Part of Copperbelt Province of Zambia.
Kribek, B., V. Majer, and I. Nyambe 2007.
Light shade = EU permissible concentrations of pollutants and Copperbelt unspoilt conditions; White shade = Zambia permissible limits; Dark shade = over the limits

However, the Kříbek *et al.* (2007) investigation of industrial pollution does not cover the general area of Kabwe, an industrial town located in the Copperbelt south of the study area considered in this section. Yet Kabwe is considered by the Blacksmith Institute as one of the 10 most polluted cities on the planet. Lead poisoning is particularly prevalent in this city which has a population of 300,000.[20] The Blacksmith Institute urged the World Bank to provide significant funding to remove toxic lead from the soil in Kabwe as its population was severely sick and incapacitated from chronic lead exposure.

Heavy metals are also easily taken up by biota during respiration as well as from sediments by bottom feeders. Excessive heavy metals are toxic to most life forms and as they move through the food chain, heavy metals accumulated in aquatic species (mostly fish). In turn, these accumulate in the human population, resulting in serious health problems. There is no evidence that the heavy metal pollution from mining activities has progressed to this stage, but monitoring must be established to ensure that this does not happen.

3.8.4 Pollution from the industrial sector

Industrial pollution of water ranges from nutrients already present due to agriculture and domestic pollution, to heavy metals normally associated with mining activities. Sulfate and sulfides often associated with metal processing and hydrocarbons from oil refineries and the motor industry are typically problematic. Although there are a significant amount of industries in the areas in which mining occurs, there is no specific data on the pollution generated by these particular industries.

The water use by a collection of main industries was estimated by the Sector Study (Denconsult 1998e) to be approximately 31 million m^3 per year, which results in 13 million m^3 of effluent being discharged into water courses each year. The report by Beilfuss and Brown (2006) also expressed concern as to the effluent discharged into the Zambezi River by the Sugar Mill located at Marromeu in the Delta. However, there is no data to suggest that this in fact a problem. The flow in the Delta very seldom drops below 400 m^3 per second, and hence the effluent will be sufficiently diluted so as not to have any discernable impact.

Table 3.109. gives a very rough overview of some of the main types of industries found in the Zambezi River Basin and the type of waste that is typically associated with them.

3.8.5 Additional water quality issues

The report by Beilfuss and Brown (2006) mentions two other water quality-related issues. First, the trapping of sediment in Lake Kariba and Lake Cahora Bassa is changing the natural sediment loads in the lower Zambezi River which results in the degradation of the coastal shelf, erosion of river banks, and decreased supply of micro nutrients to the Delta. Secondly, decreased flows contribute to the intrusion of salts and increased salinity in the Delta's water as outlined earlier. Farmers on the

Table 3.109. Industrial waste in the Zambezi River Basin

Subbasin	Type of industry	Typical waste/pollution challenge
Kafue (7)	Breweries, oil processing, lead batteries, paint, paper, galvanization, tannery, chemical processing, textiles, and sugar.	Biochemical oxygen demand, organic, solvents, heavy metals, petroleum waste, zinc slurry, and nutrients.
Kariba (6)	Breweries, oil processing, tannery, chemical processing, textiles, sugar mill, iron and steel, and metallurgy.	Biochemical oxygen demand, nutrients, chromium sludge, heavy metals, and organic solvents.
Shire River and Lake Malawi/Niassa/Nyasa (2)	Sugar mill.	Biochemical oxygen demand, and nutrients.
Zambezi Delta (1)	Sugar mill.	Biochemical oxygen demand, and nutrients.

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[20] For more information, see: www.blacksmithinstitute.org/projects/regions/africa.

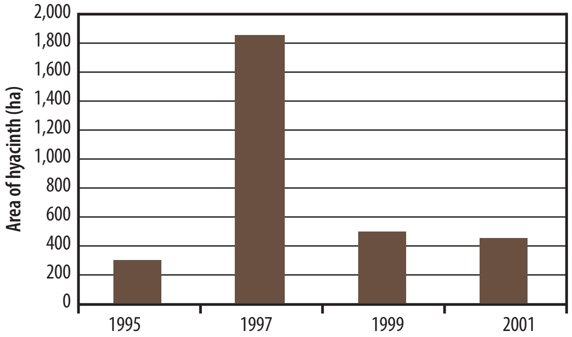
Delta have reported that the water in the Zambezi River in increasingly saline, and there is evidence of a buildup of salts on irrigated lands. Under natural conditions these salts would be flushed out by floods that would inundate the flood plain.

An additional pollution related challenge in the ZRB, and possibly most visible impact of pollution, is the growth of water hyacinth. The water hyacinth flourishes in nutrient enriched water and is a particular problem on Lake Kariba. While it is now under control, the governments of Zambia and Zimbabwe considered it to be a national emergency in 1998 when it was at its worst (ZRA 2002). Water hyacinth first appeared in the mid-1980s. Thick mats started to form in 1994, and in 1997 access to some harbors was blocked off. This impaired the fishing and ecotourism industries (ZRA 2002). There was also concern that the hyacinth would block the inlets to hydropower plants. In 1998 a committee was formed to address the problem, and with a combination of herbicides, biological control, and mechanical control, the areas covered by the water hyacinth on Lake Kariba have decreased substantially from the peak in 1998 (see figure 3.13.).

3.8.6 Water quality management

The mission of the Zambezi River Authority (ZRA) is to cooperatively manage and develop the water resources of the Zambezi River Basin (IRB-BRL-ZRA 2004). The ZRA manages the Kariba Dam and Lake complex, including the management and oversight of water quality monitoring. As part of the ZRA's environmental monitoring program, water is regularly collected at 22 sites for testing a series of parameters (some every month, every six month or once a year). While the ZRA is a bilateral organization addressing the needs of both Zambia and Zimbabwe with regard to the management of the joint water resources of the Zambezi River, monitoring carried out by the ZRA benefits both upstream and downstream parts of the ZRB.

Figure 3.13. Estimated area covered with water hyacinth on Lake Kariba



Source: ZRA 2002.

The water quality monitoring network initially only monitored quality within Lake Kariba. The network is now being extended to include all the points indicated on the map presented in figure 3.14.

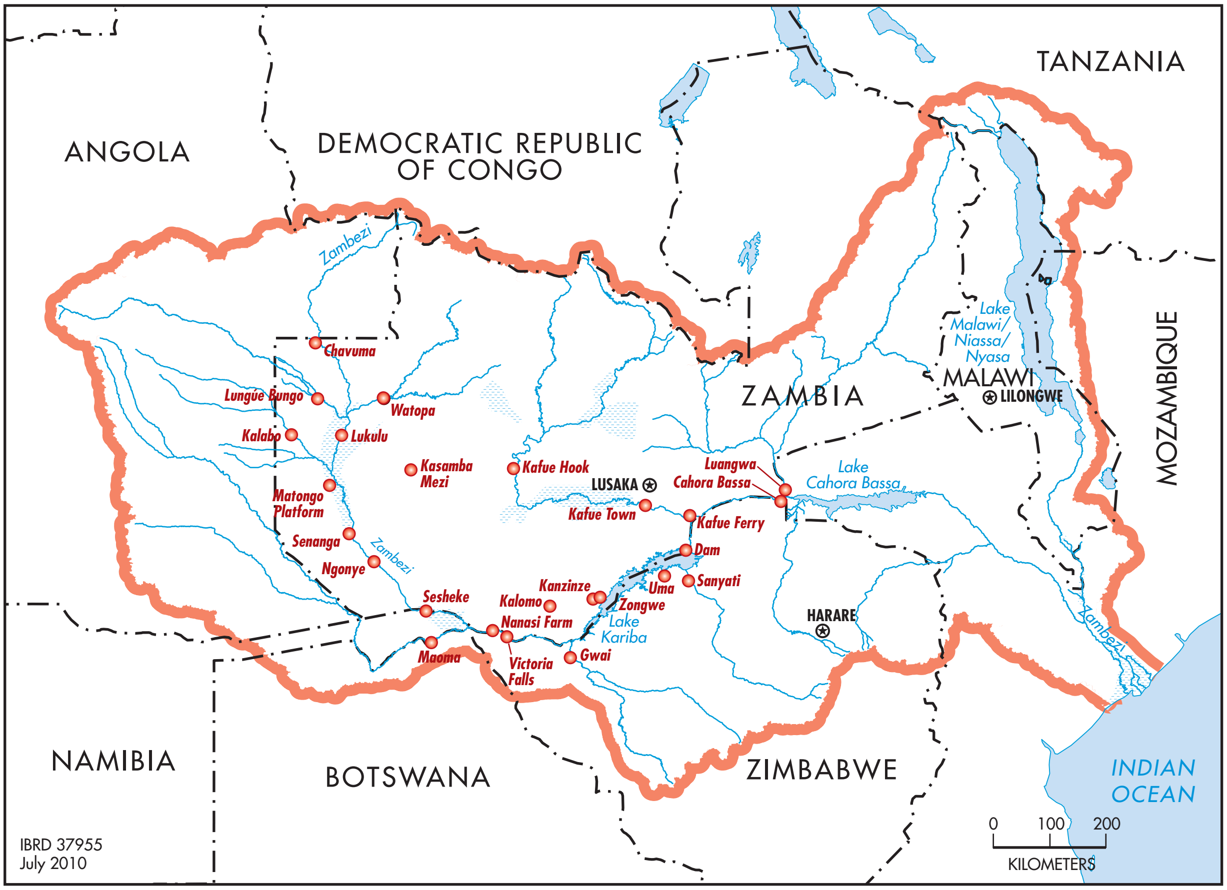
ZRA performs two levels of water quality monitoring. The first involves measuring pH, Conductivity, total suspended solids, nitrate and sulfate. The testing is carried out four times a month at Chavuma and Lungwebungu (Zambian name for the Lungúe Bungo River), and once a month at Victoria Falls and downstream of Lake Kariba. The second level monitoring includes testing for arsenic, cadmium, cyanide, lead, mercury, and zinc, and is performed four times a year at Deka (on the Deka River), Gwai (Gwai River), Sanyati (Sanyati River), Kafue Park, Kafue Town and Kafue Ferry (Kafue River), and Luangwa (Zambezi River).

According to the Euroconsult Mott MacDonald Report (2007), most major rivers in Malawi are monitored for biochemical oxygen demand and nitrate. According to Beilfuss and Brown (2006), there is no water quality monitoring in Mozambique.

The IWRM Strategy and Implementation Plan for the Zambezi River Basin (ZAMSTRAT 2008) identifies improving basin-wide collection and information exchange as one of key strategic actions. It also identifies the following challenges:

- More and more non-state actors are collecting data but not are sharing them;
- Data collection systems in most Zambezi River Basin countries are in a state of deterioration due to non-repair of gauging stations;
- Hydrological agencies often have insufficient financial and human resources even to maintain regular data collection. In some cases backlog of data is not processed;
- Vandalism of hydro-meteorological stations;

Figure 3.14. Water quality monitoring network of the Zambezi River Authority (2008)



Source: IRB-BRL-ZRA 2004.

- Groundwater monitoring networks are sparse; and
- Functioning water quality stations are scarce.

The Strategy recommends the following actions:

- Improve data collection, with priority to water quality data near hotspots and groundwater data;
- Generally overhaul gauging stations especially near abstractions and transfers;
- Develop and establish early-warning system for extreme events;
- Develop ZAMWIS as a regional tool for sharing and aligning data and warning procedures; and
- Develop water resource models and decision support tools.

The water quality standards adopted by the eight riparian countries are presented in table 3.110.

3.8.7 Conclusion

Although the large flows within the Zambezi River Basin provide extensive natural dilution, there are some key areas of concern. These are:

- Effluents and mine drainage in the Copperbelt Province is thought to enter the waterways but more data and research assessing both extent and impact of these sources for pollution is urgently needed. Monitoring the pollutants is particularly important as the Kafue River Basin concurrently supplies almost half of the domestic water in Zambia.

Table 3.110. Water and effluent quality in some basin countries

Country	Water quality/effluent standards
Botswana	Botswana Bureau of Standards BOS 32: 2000, Water Quality—Drinking Water—Specification Botswana Bureau of Standards BOS 93: 2004: Standard to Discharge Waste Water into the Environment
Malawi	Malawi Bureau of Standards WHO Drinking Water Quality Guidelines, 1993;
Tanzania	Second schedule of the Water Utilization (Control and Regulation) Act (1984) WHO Drinking Water Quality Guidelines, 1993;
Zambia	Quality of Trade Effluent into a Public Sewer, Local Administration Regulation Act (No. 161), 1985; Wastewater Regulations into an Aquatic Environment, 1993, prepared by the Environmental Council of Zambia; Zambian Standard Specification for Drinking Water Quality, prepared by the Zambia Bureau of Standards WHO Guidelines for Drinking Water Quality, 1993 Australian Summary Guidelines for Protection of Aquatic Ecosystems. ZRA Water Quality Guidelines, 2002
Zimbabwe	ZRA Water Quality Guidelines, 2002

Source: IRB-BRL-ZRA 2004.

- Nutrients accumulating in parts of the catchment area, especially originating from farming in Zimbabwe, induce excessive growth of water hyacinth on Lake Kariba. The problem is deemed to be significantly resolved though the need for control measures remains.
- Domestic and industrial effluent is not treated to acceptable standards before being discharged into rivers and watercourses. This is the main cause of the hyacinth growth on Lake Kariba. The lack of adequate water sanitation can result in health problems, but there is no evidence that this is currently a problem.

Overall, water quality problems pose few critical challenges on development of hydropower and irrigation in the ZRB. New hydropower plants will largely be unaffected by water quality problems, with the one possible exception being excessive growth of water hyacinth blocking the intake works of hydropower turbines. The development of irrigation systems can be impaired if the total dissolved solids (TDS) of the water is too high and the rate of crop production decreases as a result. Although a high nutrient load in the water can be beneficial to crops, problems arise when excess algae growth enters the irrigation systems causing blockages, reducing water distribution and increases maintenance and repair costs. The TDS of water in the Zambezi River is low enough to not be a problem at the time of the MSIOA Study. Although hydropower development is unlikely to negatively affect water quality directly, it changes flow regimes and higher concentrations of pollutants could theoretically result in the receiving stream during periods of low or zero power generation. Large-scale irrigation development, on the other hand, is likely to result in increased nutrients being discharged into rivers.

4

Regional Cooperation

4.1 REGIONAL ECONOMIC COMMUNITIES

Across Africa, Regional Economic Communities (RECs) have made progress particularly in the area of market integration, infrastructure cooperation, and resource sharing. Increased intraregional trade and improvements in international competitiveness are key common objectives among Africa's integration arrangements such as ECOWAS (Economic Community of West African States), CEMAC (Central African Economic and Monetary Community), EAC (East African Community) and COMESA (Common Market for East and Southern Africa). COMESA is a preferential trade zone stretching from Liberia to Zimbabwe, within which is a free trade zone where members have either eliminated or working towards eliminating tariffs on products originating in the zone. The Southern Africa Customs Union (SACU) is the world's oldest customs union originating from 1910, today incorporating Botswana, Lesotho, Namibia, South Africa and Swaziland. Trade facilitating measures are being agreed and implemented among many of the continents RECs, harmonizing trade and trade-related regimes.

In 1992, SADC (Southern African Development Community) grew out of SADCC (Southern African Development Coordination Conference) which was originally created in 1980. The vision of SADC is "a common future, within a regional community that will ensure economic well-being, improvement of the standards of living and quality of life, freedom and social justice; peace and security for the peoples of Southern Africa". Its early program of action focused on transport and communications, agriculture, energy, and human development. Today, its mandate includes areas ranging from harmonizing business and regulatory practices to attract investment to natural resources management, from conflict resolution to the cooperation and sharing of energy (i.e., the Southern African Power Pool, SAPP). At present, SADC has 15 member countries: Angola, Botswana, the Democratic Republic of Congo, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, United Republic of Tanzania, Zambia and Zimbabwe.

Many interrelated factors may challenge the success of the regional economic communities and regional integration initiatives:

- *Proliferation and overlapping membership.* With a growing number of RECs, many countries are members of multiple arrangements resulting in a complex web of regional organizations, of which only eight are officially recognized by the AU[21] (figure 4.1.). This results in fragmented markets and approaches to regional integration; inconsistent objectives and conflicting operational mandates; contradictory obligations and loyalties for member countries; increased financial cost of country membership; duplication of programs and efforts; unhealthy rivalry for donor funds; and, consequently, reduced ability to pursue coherent and effective integration programs.
- *Limited capacity and inadequate funding.* The RECs' ability to play lead roles in successful regional cooperation and integration is often limited by inadequate mandates, capabilities, insufficient and unpredictable funding, poor remuneration for staff members (resulting in high turnover and extended vacancies), and weakened capacity. In many cases, member countries have expanded the mandate of the regional economic communities without a commensurate increase in funding.
- *Lack of supranational authority and weakened implementation of agreed programs.* A number of RECs have been unable to fully implement integration programs on a timely basis. Delays partly reflect the lack of enforcement authority, as sanctions are rarely applied to countries in breach of common agreements. This has opened a substantial gap between the stated aspirations of member countries (as expressed in the treaties and protocols creating the regional economic communities) and the reality on the ground. Regional goals have translated poorly into national plans and budgets, and regional programs have been poorly implemented at the national level. This may be explained by a general reluctance of countries to cede their national powers to regional authorities.
- *Low popular participation in the regional integration debate and agenda.* Governments and intergovernmental organizations typically dominate dialogue on integration. As a result, institutions and consultation mechanisms often exclude many relevant stakeholders and the wider population. Wider participation is increasingly being recognized, engaging among others, actors form civil society. However, integration is not limited to mere participation.
- *Lack of information regarding the costs and benefits of integration.* National benefit from regional integration and initiatives is often uncertain. Thus, national authorities are in many cases reluctant to adopt and commit necessary resources and authority to regional arrangements, often motivated by fear of revenue losses in trade and customs.
- *Controversy surrounding the path and pace of regional integration and liberalization.* Liberalization of regional trade and tariff regimes is one of the main drivers of integration schemes. The extent of liberalization remains a controversial issue, especially when regional arrangements are compromised by competitiveness. Tariff liberalization, whether unilateral or otherwise, can also affect government revenue (Dinka and Kennes 2007).

4.2 INSTITUTIONAL CONTEXT FOR TRANSBOUNDARY COOPERATION IN THE ZAMBEZI RIVER BASIN

4.2.1 SADC – framework and activities

SADC Revised Protocol on Shared Watercourse (2000)

The initial SADC "Protocol on Shared Watercourse Systems" was signed in 1995. Signatories to the agreement included Angola, Botswana, Lesotho,

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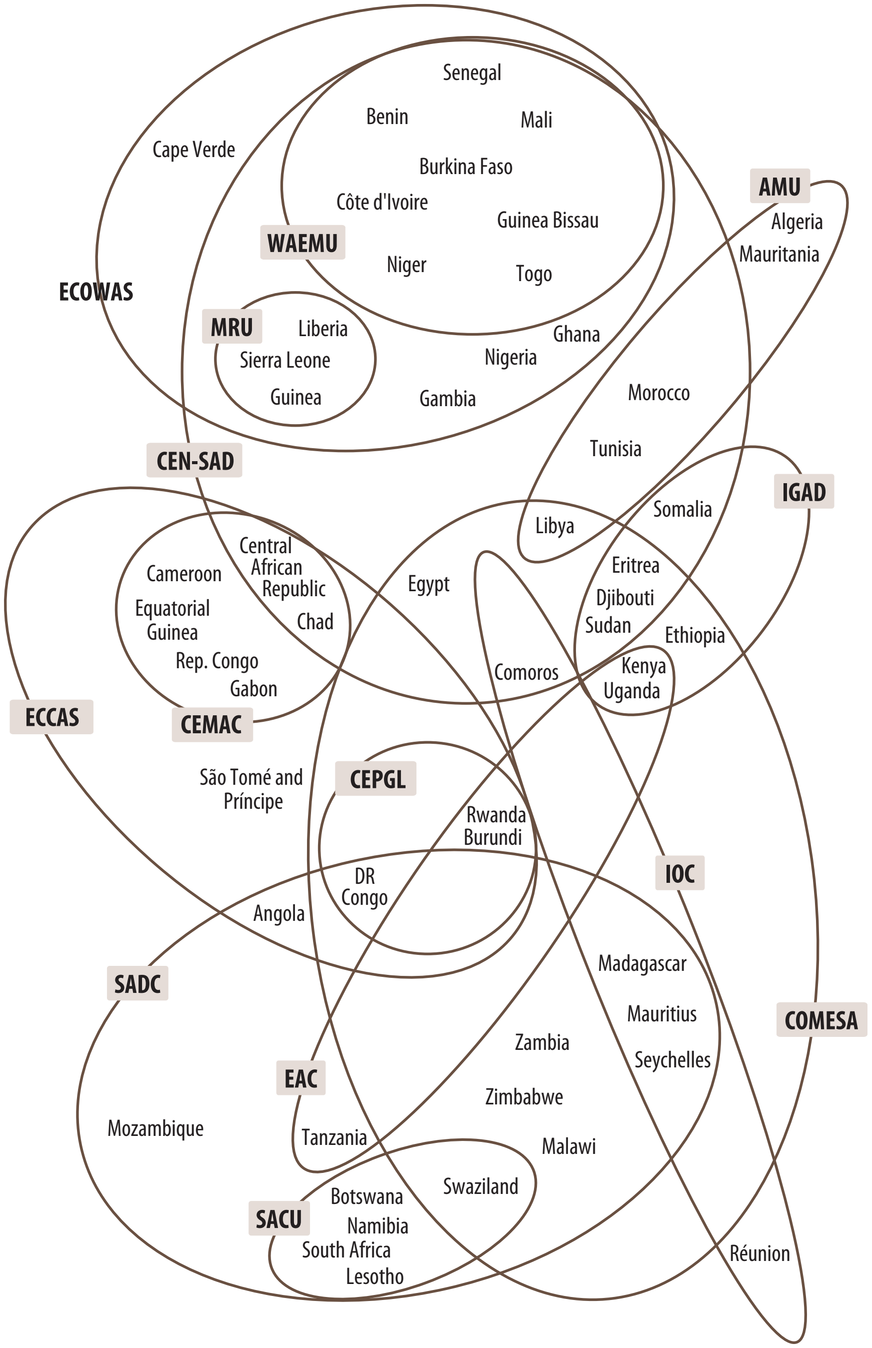
[21] The African Union recognizes the following institutions as RECs: UMA (Arab Maghreb Union), CEN-SAD (Community of Sahel-Saharan States), COMESA (Common Market for East and Southern Africa), EAC (East African Community), ECOWAS (Economic Community of West African States), ECCAS (Economic Community of Central African States), IGAD (Inter-Governmental Authority on Development), and SADC (Southern African Development Community).

Figure 4.1. Regional Economic Communities in Africa



Source: World Bank 2008.

Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe. The protocol came into force on September 29, 1998 after being ratified by a two-thirds majority of SADC member States. Since 1995, Mauritius, Seychelles, and Democratic Republic of Congo (DRC) have joined SADC and acceded to the protocol. In April 1998, discussions began to bring the protocol closer to the United Nations Convention on the Law of Non-Navigable Uses of International

Watercourses and incorporate other adjustment requested by the signatories. In 2000, the SADC member countries signed the "Revised Protocol on Shared Watercourses" to accommodate these improvements.

The original protocol established the framework for the use of watercourses shared by two or more member countries, and it emphasized the following principles: the right of each member country to use shared watercourses; maintenance of a balance between development and conservation; collaboration between riparian member countries on developments affecting shared watercourses; free exchange of relevant information between riparian countries; and, the pursuit of equitable exploitation of the River's resources among member countries. Furthermore, the protocol outlined a number of specific obligations for the member countries on prevention of pollution, elaboration of impact assessments, prevention of introduction of alien species, and notification in emergency cases, among others. Member countries view the protocol on shared watercourse systems as a high priority for developing sustainable water resources management for the regions scarce water resources and for reducing and resolving conflicts over these resources.

The revised protocol clarified certain concepts and procedures. The role of water for environmental sustainability or water for the preservation of ecosystems was emphasized. Management aspects of shared watercourses were equally strengthened-comprising development and planning, implementation of any agreed plans, and promotion of rational, equitable, and optimal utilization, protection, and control of shared watercourses. The revisions incorporated measures to prevent pollution of and any significant harm to the watercourses. Furthermore, the meaning of watercourses was redefined to include both surface and groundwater.

The overall objective of the revised protocol is to further foster cooperation between member countries, and seeks to promote the following in particular:

- The establishment of agreements and institutions for the management of shared watercourses;
- The sustainable, equitable, and reasonable use of the shared watercourses;
- The coordinated, integrated, and environmentally sound development and management of shared watercourses;
- The harmonization and monitoring of legislation and policies for planning, development, conservation, and protection of shared watercourses and their resources; and
- Research and technology development, information exchange, capacity building, and the application of appropriate technologies in management of shared watercourses.

In addition, the revised protocol includes a set of general principles. Member countries have committed to participate in the use, development, and protection of a shared watercourse—including both the right to use the watercourse and the duty to cooperate in its protection and development (taking into account all relevant factors such as the environmental needs; populations dependent on the shared watercourses; conservation, protection, development and economy of use of the water resources and the costs of measures taken to that effect; and, the availability of alternatives, of comparable value, to a particular planned or existing use).

The institutional mechanisms responsible for the implementation of the revised protocol are:

- SADC:
  - the Committee of Water Ministers
  - the Committee of Water Senior Officials
  - the Water Sector Coordinating Unit
  - the Water Resources Technical Committee and Sub-Committees
- Shared Watercourse Institutions, which are described in the following excerpts from the protocol:
  - Member countries undertake to establish appropriate institutions, such as watercourse commissions, water authorities, or boards as may be determined;
  - The responsibilities of such institutions shall be […] in conformity with the principles set out in this protocol; and
  - Shared Watercourse Institutions shall provide on a regular basis, or as required by the Water Sector Coordinating Unit, all the information necessary to assess progress on

the implementation of the provisions of the protocol.[22]

SADC Drought Monitoring Center in Gaborone

The SADC Drought Monitoring Center was established in the early 2000s. One of the center's main services is delivering regular regional weather forecasts at subregional level, especially on rainfall. Relevant government authorities in charge of water resource management in the region use these forecasts, often communicated via newsletters. The forecasts are also crosschecked with SARCOF (Southern Africa Regional Climate Outlook Forum) and it contributes to alleviating the weaknesses in hydrometric networks across the region.

Southern African Climate Outlook Forum (SARCOF)

The Southern African Climate Outlook Forum (SARCOF) is a collaborative effort between a series of organizations. They include the SADC Drought Monitoring Center (DMC) and the World Meteorological Organization (WMO), United Nations Inter Agency International Strategy for Disaster Reduction (UN/ISDR), the Department of Meteorological Services of Lesotho, and other partners. It convenes annually to deliver prospect over the next coming rainy season. The SARCOF outlooks applies primarily to the period covering major seasons and applies only to relatively large areas. Hence the forecasts may not account for intra-seasonal or local variations.

4.2.2 The Zambezi River Watercourse Commission (ZAMCOM)

Negotiations to establish a Zambezi River Watercourse Commission (ZAMCOM) began in the late 1980s but were postponed due to a shift in focus to the SADC Protocol on Shared Watercourses. In 1987, however, SADC facilitated the initial discussions on an agreement between the eight riparian countries (Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe) to promote joint management of the water resources of the Zambezi River Basin. The Action Plan for Environmentally Sound Management of the Zambezi River (ZACPLAN) was subsequently launched with a series of integrated projects, known as the Zambezi Action Plan Projects or ZACPROs. The projects aimed to address both technical and political initiatives, including support to preparation of a Zambezi River Watercourse Commission (ZAMCOM). The core project of the ZACPLAN, ZACPRO 6, focuses on establishing an enabling environment for the goals of ZACPLAN and the development of an integrated water resources management strategy for the Zambezi River Basin (ZAMSTRAT).

The first phase of ZACPRO 6, 1995–1999, included the developing of a data system (ZACBASE) and water use sector studies, with minimal attention to the institutional environment in which such planning tools and models were to operate. In due course, a draft ZAMCOM Agreement was produced and the inital detailed negotiations among the riparian countries took place in 1998. The negotiations were terminated later in the same year when one riparian country, Zambia, withdrew. Zambia's ongoing policy and legislative reforms encumbered international water resources management and capacity. Nevertheless, it was agreed that the process should meet the needs of all SADC Member States in line with the provisions of the Revised SADC Protocol on Shared Water Courses.

The ZACPLAN process was revived in October 2001, through the launch of the ZACPRO 6, Phase II Project (ZACPRO 6.2) with the financial assistance of the governments of Sweden, Norway and Denmark. The immediate objectives of ZACPRO 6.2 lasting 2001–2009, were to: (i) setup the regional and national enabling environment necessary for strategic water resources management through ZAMCOM; (ii) establish water resources management systems including models, tools and guidelines; and (iii) develop an integrated water resources management strategy.

To meet the first objective of setting up an enabling environment for the ZAMCOM, negotiations led to an updated version of the draft ZAMCOM agreement which was signed by seven of the eight

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[22] If a dispute among member states cannot first be settled amicably, it shall be referred to the SADC Tribunal as provisioned in the SADC Treaty.

riparian countries on July 13, 2004. The agreement will come into force with ratification by a two-thirds majority (or six of the eight riparian countries). To date, out of the seven countries that have signed the agreement, five have ratified. Zambia still has not signed and is awaiting conclusion of the policy reform process and institutional alignments. Once established, the ZAMCOM Secretariat is expected to assume the responsibility for ZACPRO 6.2 project. In the meantime, ZACPRO 6.2 has been coordinated by the SADC Water Division and the majority of implementation has been done by the Zambezi River Authority (ZRA) on behalf of the riparian countries.

As part of the second objective to develop models, tools and guidelines, the Zambezi Water Information System (ZAMWIS) was established.

The third objective resulted in the development of the Integrated Water Resources Management Strategy and Implementation Plan for the Zambezi River System in 2008 (ZAMSTRAT). ZAMSTRAT acknowledges certain weaknesses in the approach to ZAMCOM and makes recommendations on how to address these. They are presented in four broad categories outlined in table 4.1.

ZACPRO 6.2 came to an end on April 30, 2009 and was supposed to cede its functions to ZAMCOM. In July 2009, in the absence of a ratified agreement, the riparian Ministers responsible for water adopted an Interim ZAMCOM Governance Structure with all riparian countries agreeing on the establishment of an interim secretariat to be located in Gaborone, Botswana.

Governance structure

When the agreement is ratified, the Zambezi River Watercourse Commission will be a regional organization with legal status empowered to enter into contract, acquire and own property, sue and be sued on behalf of the riparian countries. This is applicable in the territory of each member country. In practical terms, it is feasible that the ZAMCOM could become the owner of some shared equipment and assets at river basin level.

The Zambezi River Watercourse Commission is foreseen to include:

- *The Council of Ministers* that comprises the ministers in charge of water resources of each member state. It will convene at least once a year, elect a chairperson and a vice chair, and make decisions by consensus. The Council is expected to be in charge of the overall guidance, strategic planning supervision, financial overview and decisions, connecting with institutions outside the Zambezi River Basin, and evaluation of programs.
- *The Technical Committee (ZAMTEC)* will comprise not more than three members from each member country, plus advisors as determined by each country. It will convene at least once a year, have an elected chair and vice chair, and decisions will be made by consensus. The Committee will be in charge of implementing policies and decisions of the Council, developing the strategic plan, developing hydrometric data and early-warning systems, and monitoring water abstraction. The Committee will also make legal, political, and technical recommendations to the Council and appoint staff and supervise the Secretariat.
- *The Secretariat (ZAMSEC)* will comprise the Executive Secretary, and technical and supporting personnel as approved by the Council. The Secretariat is to be in charge of implementing decisions and guidelines determined by the Committee and provide support on all issues (administrative, legal, technical, budgetary, planning, information technology, hazard awareness, etc.).

By signing the ZAMCOM agreement, the riparian member countries are obliged to promises made through technical, legislative, administrative committments, and its other aspects of shared management of the Zambezi River. They also have to conduct their management plans, projects, and programs in accordance with the ZAMSTRAT, as well as collaborate closely in their respective countries with civil society, institutions, and organizations responsible for water use, development and management. Riparian member countries commit themselves to furnish, collect, and process data when and where appropriate at a reasonable cost. They also employ their best efforts in developing standardized methodologies for data collection, processing and exchange.

The core budget of the Commission is mainly drawn from direct contributions from member countries and any other funding sources for specific functions from donors or international organizations.

Table 4.1. ZAMCOM – recommendations for improvement (ZAMSTRAT)

Integrated and Coordinated Water Resources Development

Weaknesses	Actions
Inadequate water infrastructure for achieving regional energy security.	• Joint development of feasible package of major hydropower sites, taking into account multiple functions in coordination with SAPP. • Identify and promote options for small scale hydropower development.
Insufficient water infrastructure for agricultural development to achieve regional food security.	• Support the development of agriculture through basic facilities such as reliable input supply and better road networks. • Expand irrigated agriculture. • Promote and support the restoration and sustainability of flood plain agriculture. • Enhance the productivity of rain-fed agriculture through improved water management options.
Major dams in the Basin were constructed for a single purpose and their operation is not optimized for multiple uses.	• Develop appropriate river simulation models to identify the influence of dam operations on the river flow regimes, especially downstream, including unregulated tributaries. • Optimize multi-purpose management of existing and planned future reservoirs.
Inadequate financing of water resources development and management.	• Improve overall investment climate to make water development infrastructure financing more attractive. • Develop mechanisms for local infrastructure co-financing. • Raise awareness of the vital role of the water sector in economic development and poverty alleviation. • Enhance the role of parliamentarians in improving the business and investment environment. • Motivate private sector development in support of poverty alleviation.
Low access to Water Supply and Sanitation.	• Expand coverage of water supply and sanitation services in rural and urban areas.

Environmental Management and Sustainable Development

Weaknesses	Actions
Inadequate protection and sustainable development and use of wetlands.	• Improve the wetland related regulation and management within and between riparian countries. • Assess and maintain environmental flows appropriate to each river section on its course. • Develop management plans for all the major wetlands in the Basin taking into account the different wetland functions and services. • Develop and implement special initiatives for environmental management around hotspots, as pilot cases to later be extrapolated elsewhere in the Basin and beyond.
Deterioration of water quality due to point pollution from mining, industrial and urban centers.	• Set up integrated water quality monitoring system. • Harmonize legislation and enforcement systems. • Promote clean technology. • Conduct regular research of emerging pollution challenges.
Proliferation of invasive aquatic weeds.	• Harmonize the legislation on the control of aquatic weeds. • Set up appropriate national and regional focal points on aquatic weed control. • Initiate national and regional capacity building programmes. • Initiate joint monitoring and survey of aquatic weeds and others. • Adjust reservoir operations (including provision for weed control).
Unsustainable and low-productivity fisheries management.	• Collaborate with the New Partnership for Africa's Development (NEPAD) program towards improving fisheries productivity. • Integrate fisheries development with water resources planning, management and development—including new reservoir operating rules, fishery production, and provision for fish migration.
Tourism development is threatened by degradation of the aquatic environment.	• Systematically integrate tourism development in water resources planning, development and management. • Develop catchment management plans, incorporating areas of tourism value, such as intrinsic game management areas and wetlands. • Operate water-related infrastructure in support of tourism management.

Continued on next page

Table 4.1. ZAMCOM – recommendations for improvement (ZAMSTRAT) *(continued)*

Environmental Management and Sustainable Development

Weaknesses	Actions
High-value and unique ecosystems and related ecological and economic functions in the Basin may be threatened and fragmented by accelerated development.	• Prepare a comprehensive and spatially explicit map of ecosystems functions and services. • Delineate high priority conservation areas, such as headwaters, recharge zones and flood plains and implement land use plans for such areas. • Start international cooperation on linking areas with high significance for biodiversity—coming to Protected Area Networks—vis-a-vis the Transfrontier Conservation Areas. • Develop and implement guidelines for the use of proper environmental and social impact assessments in developmental planning and management.

Adaptation to Climate Variability and Climate Change

Weaknesses	Actions
Extreme variability and uneven distribution of rainfall is likely to be amplified by climate change.	• Carry out comprehensive assessment of the vulnerability of basin water resources to climate change.
Lack of integrated flood management in development planning.	• Integrate flood management in development planning. • Develop and implement effective land use planning. • Strengthen and encourage collaboration of existing early flood warning institutions. • Dovetail the operation of major water infrastructure to optimize flood attenuation. • Formulate comprehensive flood preparedness and flood response mechanisms, sharing possible benefits of regional good practices.
Poor drought management and integration in development planning.	• Support the development of drought management plans, including local irrigation schemes, improved food stock logistics, crop adaptation and drought insurance. • Mainstream drought forecasting in water resources planning, development and management.
Inadequate coping mechanisms for climate change.	• Integrate strategies to deal with climate variability in national socioeconomic development planning and management. • Exploit development opportunities under the global climate change protocols for afforestation and reforestation at national as well as regional level. • Setup a regional center of excellence to document and support activities for effective adaptation to climate variability and climate change.

Basin-wide Cooperation and Integration

Weaknesses	Actions
Absence of a river basin organization for the whole Zambezi River Basin.	• Encourage signing and ratification of the ZAMCOM Agreement and establish and operationalize ZAMCOM—through promotion of targeted measures to raise awareness of benefits of basin-wide development and management of its water resources. • Urgently establish an Interim arrangement for ZAMCOM Secretariat. • Develop public information function initially of the Interim and later permanent ZAMCOM Secretariat. • Strengthen coordination and networking with key institutions with ongoing programs in the Basin (such as SADC, COMESA, SAPP, NEPAD, Waternet, IUCN, WWF, WHYCOS, World Bank etc.), including management commissions of subbasins (Joint Water Commissions, Zambezi River Authority).
Weak capacity of national water management institutions to perform river basin management tasks.	• Develop and implement performance based training programs on water resources planning, development and management based on institutional development assessments. • Implement well-designed basin-wide strategic plan to harmonize water resources planning, development and management policies, legislation and strategies of the riparian countries.

Continued on next page

Table 4.1. ZAMCOM – recommendations for improvement (ZAMSTRAT) *(continued)*

Inadequate water resources knowledge base for basin-wide planning, development and management.	• Formulate and implement a data and information sharing protocol for further operationalization of ZAMWIS as well as the January 2010 Regional Awareness and Communication Strategy for the SADC Water Sector. • Harmonize data measurement and management methods and systems across the Basin. • Improve basin-wide data collection systems (water quality and quantity measurements, sediment load, and groundwater). • Priority improvement of data and knowledge base on groundwater resources. • Further development of ZAMWIS (increasing accessibility and interactivity and developing models and decision support system tools). • Strengthen basin-wide research on water resources through riparian-joint programs, collaboration of research institutions, and enhanced information exchange.
Inadequate effective stakeholder participation in water resources development and management.	• Strengthen stakeholder participation through policy and legislation review and revision throughout the riparian countries. • Formulate and implement a public information program to raise awareness among a broad range of stakeholders. • Strengthen and sustain the Annual Basin Water Forum meetings as part of awareness and information sharing among basin stakeholders.

Source: Euroconsult 2008a.

A member country may withdraw from the agreement at any time during the three years after entry into the agreement and after 12 months notice to the Commission. Any asset of the Commission located on the territory of a withdrawn riparian member country shall remain the property of the Commission with no possible claim from the said country.

Operationalizing ZAMCOM

An agreement is still pending on when an interim ZAMCOM Secretariat can be established. Two immediate objectives and related outputs have been agreed upon, and are summarized in table 4.2.

The immediate objectives and outputs of the interim ZAMCOM are: (i) to set up a functional interim Secretariat of ZAMCOM; (ii) implement the plan for operationalizing the ZAMCOM; and (iii) support implementation of the prioritized short-term actions stipulated in the ZAMSTRAT.

4.2.3 Additional shared watercourse agreements in ZRB

Zambezi River Authority

The Zambezi River Authority (ZRA) between Zambia and Zimbabwe was established in 1987 through

Table 4.2. Interim ZAMCOM objectives

Objective	Outputs
1. ZAMCOM and its components operating effectively.	1.1 ZAMSEC supporting the Council of Ministers and ZAMTEC efficiently and effectively. 1.2 Zambezi Trust Fund established and functioning effectively. 1.3 ZAMCOM I&C Strategy developed and implemented. 1.4 ZAMCOM Organs and Member Countries capacitated to implement ZAMCOM Agreement effectively. 1.5 Studies and Research according to needs and requests from ZAMCOM.
2. Strategic Plan for the Zambezi River Basin agreed and being implemented to guide efficient management and sustainable development of the Zambezi Watercourse.	2.1 Strategic Plan developed and approved. 2.2 Priority Projects identified, funding packages developed and projects implemented.

endorsement of the Zambezi River Authority Act. The purpose of the Act was primarily the effective management and water use of the Kariba Dam and reservoir to enable improved hydropower generation and delivery to the two major national electricity utilities, ZESCO and ZESA. The agreement has also enabled joint development of new schemes and sharing of costs.

The Shire River and Lake Malawi/Niassa/Nyasa Water Resources Management Initiative

In 2005, Malawi, Mozambique, and Tanzania signed a MoU for the management of shared water resources of the Shire River and Lake Malawi/Niassa/Nyasa subbasin. The initiative includes proposals for the development and adoption of a subbasin agreement on common management and use of water resources by the three riparian countries; capacity building and training in integrated water resources management; and, strengthening water resources monitoring systems.

4.2.4 Institutional arrangements in riparian countries

The eight riparian countries sharing the Zambezi River Basin have different institutional arrangements for managing water resources. Figure 4.2. gives a schematic overview of how each riparian country has organized its institutions. In most countries, the responsibility to manage a country's water sector lies with several ministries, departments and authorities. Concurrently, the same agencies can be responsible for other sectors such as mining, energy, agriculture, or forestry. The application of IWRM across sectors as well as to what degree multiple stakeholders are involved differ depending on the particular arrangement for each country. Hence, the institutional context at national level will directly impact application of IWRM at the basin level.

Water allocation, and in most cases water resources planning and management, are still centralized functions that depend on the central state and administrative boundaries. Furthermore, there is a need for more formal distinction between regulators and water users at basin level.

4.2.5 Information Management Systems

Strengthening integrated water resources management at basin, national and local level depends on two issues in particular: the degree of stakeholder representation and participation; and the collection, management and exchange of hydrometric and hydrologic information and data.

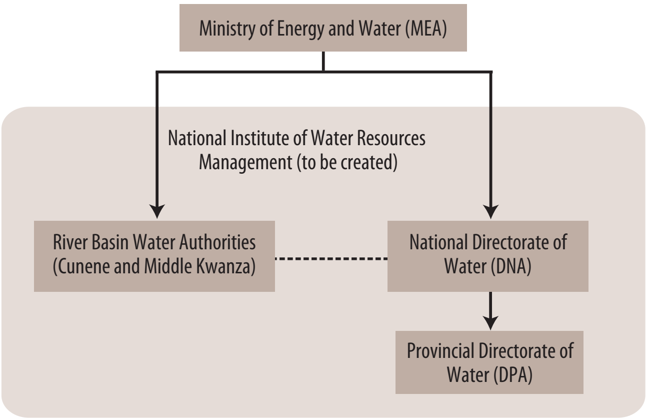
In a majority of the riparian countries, management of water resources is highly centralized with limited stakeholder representation and participation in decision making. Zimbabwe and Mozambique are the two countries with most advanced decentralization and stakeholder representation. Both have established basin councils or committees for this purpose. In Zimbabwe, Catchment Councils have the mandate and authority over water use licenses and water allocations and they coordinate their actions with the regional delegations of the Zimbabwe National Water Authority (ZINWA), but do not depend on it for their decisions.

In Mozambique, the Regional Water Associations (ARAs)—and specifically ARA-Zambeze—are semi-autonomous institutions under the Ministry of Public Works and Housing. They are autonomous in their administrative and financial processes and have the right to own property. ARAs retain revenues from water use licenses to sustain their operations. Their duties include the management of water resources, water allocation and controlling water quality. The Zambezi River Committee comprises 55 members. It is chaired by ARA-Zambeze which also manages discussions and procedures. Members represent various interests: hydropower, the Marromeu sugarcane scheme, community leaders, authorities, major industries (such as tobacco), coal mines (CVRD), World Wildlife Fund, and minor associations (such as fisheries and farmers). The Committee meets at least twice a year, once before the rainy season and at the beginning of the dry season. The Committee is to become an autonomous body with an elected chairperson.

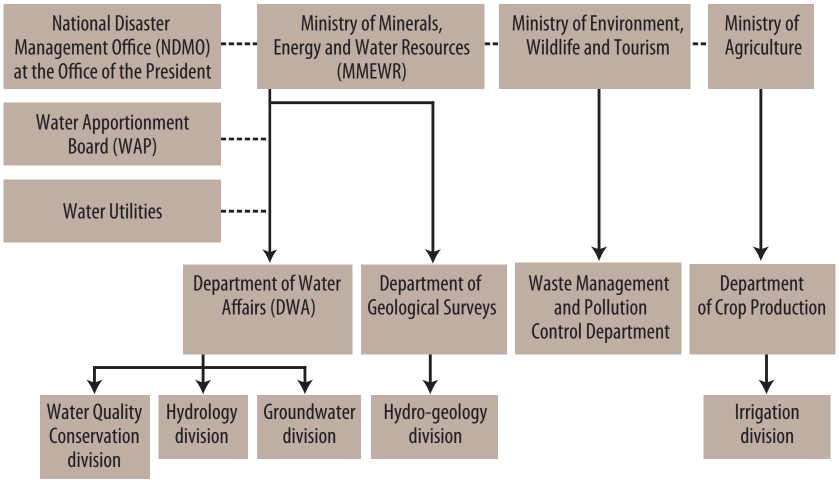
The second major concern in all riparian countries is the collection, management, and exchange of hydrometric and hydrologic data. Availability of data has deteriorated due to several factors. Networks of gauging stations for data collection have often not been maintained, have been vandalized

Figure 4.2. Institutional arrangement for water management in the riparian countries of the Zambezi River Basin

Angola



Botswana



Malawi

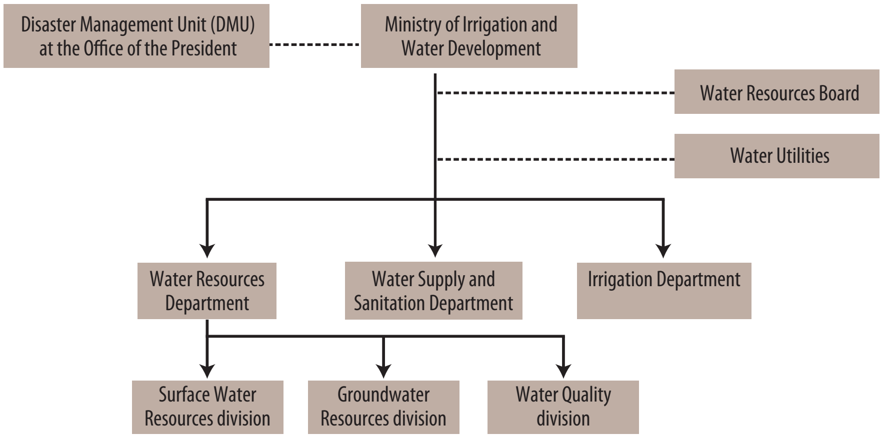


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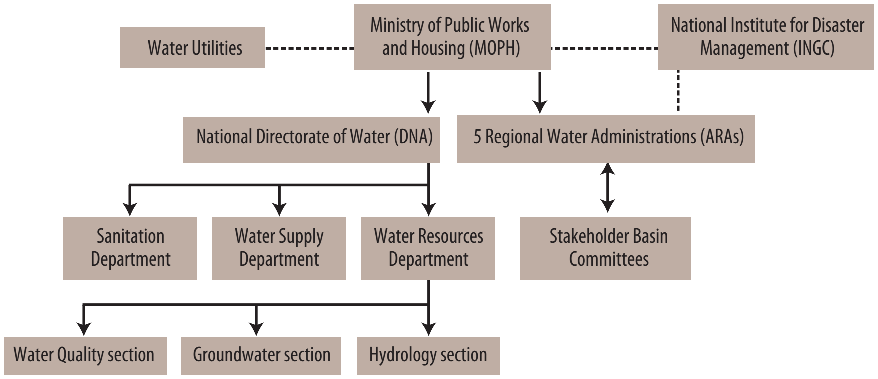
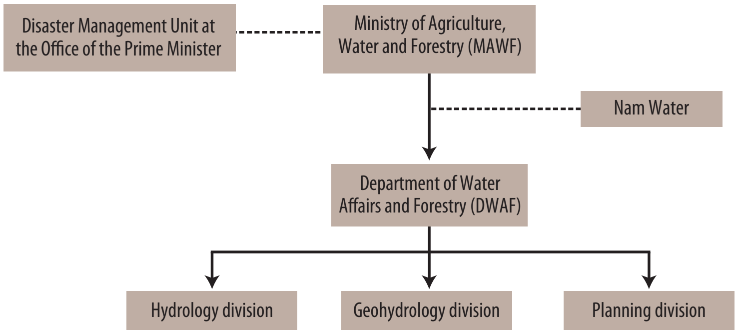
Figure 4.2. Institutional arrangement for water management in the riparian countries of the Zambezi River Basin *(continued)*

Mozambique



Namibia



Tanzania

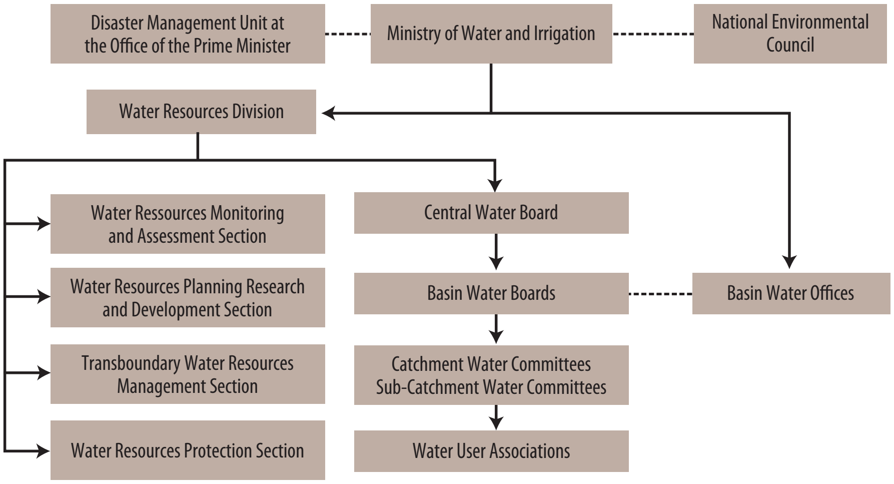


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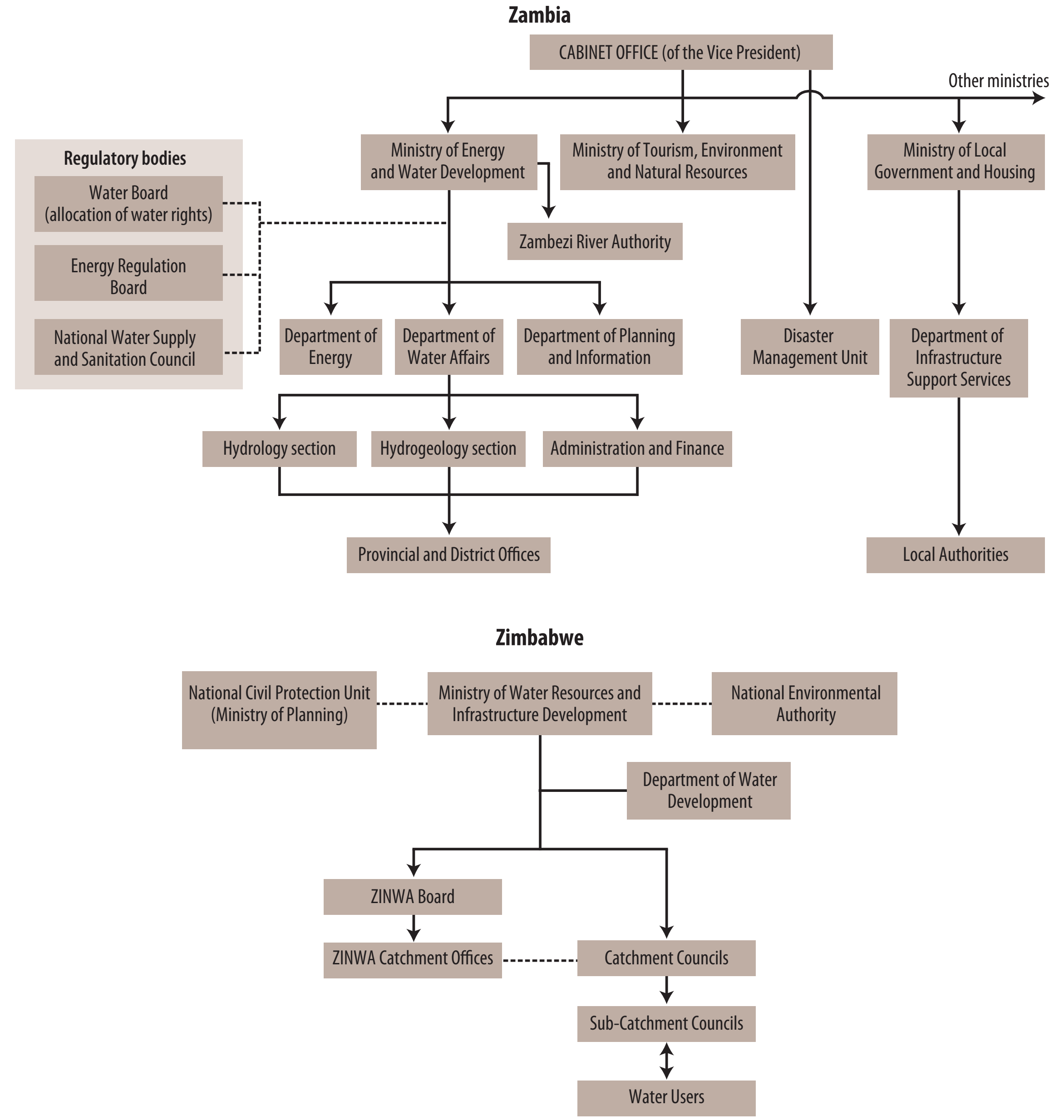
Figure 4.2. Institutional arrangement for water management in the riparian countries of the Zambezi River Basin *(continued)*



Source: Euroconsult Mott MacDonald 2007. www.maji.go.tz

or are absent in many parts of the Basin. This underpins much of the problems later encountered in the wider information management systems (IMS).

In some countries, the responsibility for data collection is shared between other institutions (such as dam operating authorities) as well as the national water department. As such, there are differences in the quality and type of data collection across the country, and sometimes a lack of communication between the institutions. In many countries, there is a lack of funding to maintain a functioning IMS for hydrometric and hydrology data. This negatively impacts the level of technology that staff can use as well as motivation to keep the systems running.

Transferring data from the collection station into the bigger IMS often managed centrally, is often done by postal services which means that exchange of information suffer delays. Many departments responsible for the IMS suffer backlog of data that has not been processed and archived. Groundwater monitoring systems are sparse or nonexistent in most riparian countries. The situation is the same for data relating to quality of water resources. Furthermore, the use of different data management systems and models has impaired exchange of data further (for example, HYDSTRA, HYDATA, and text for river flow data, and many more for meteorological data).

As a result, joint planning and monitoring of water resources at the level of the Zambezi River Basin requires addressing many of the above mentioned challenges at national level. Even optimal management of existing large hydraulic works, such as Kariba and Cahora Bassa dams, is hampered, as is crucial prevention of disastrous flooding.

For the purpose of flood management, ARA-Zambeze relies primarily on global data released by SARCOF (Southern Africa Regional Climate Outlook Forum) or INAM (National Institute of Meteorology), and selected websites such as NOAA and EUMETSAT. ARA-Zambeze also processes discharge estimates based on the rain forecast using a new system developed with the MIKE 11 software and adapted to the Zambezi River Lower system by DHI. However, accuracy remains weak in flat areas due to lack of realistic terrain models. Moreover, heavy rain falls in tributaries to the Zambezi River, below Cahora Bassa Dam, that are not gauged and measured and which lead to flooding downstream.

Under ZACPRO 6.2, initiatives were made to consolidate available data in one single database. As part of the Zambezi Water Information System (ZAMWIS), this database is intended to be the responsibility of the ZAMCOM Secretariat and rely on data from the riparian countries. Data integrity remains the responsibility of individual countries.

As a regional part of the World Meteorological Organization (WMO), the SADC Hydrological Cycle Observing System (SADC HYCOS) project aims to improve basic observation activities, strengthening regional cooperation and promoting free exchange of data in the field of hydrology. Among other activities, SADC HYCOS involves an integrated regional water resources database and website that is supported by a network of telemetric stations distributed across the region. These stations communicate directly with the database via satellites. Data is accessible through the website which is password protected. Unfortunately, several stations have suffered from vandalism as they are not protected or guarded.

4.2.6 National management arrangements for the Zambezi River

Gabinete do Plano de Desenvolvimento da Região do Zambeze (GPZ)

The Gabinete do Plano de Desenvolvimento da Região do Zambeze (GPZ) in Mozambique (the Zambezi River Valley Development Authority) is a multipurpose government institution that promotes, plans, coordinates and supervises the resources in the Zambezi River Valley. The concerned sectors range from rainfed agriculture and fisheries, to small scale hydropower and aquatic ecosystems. The GPZ is institutionally positioned directly under the authority of the Council of Ministers of Mozambique. It is an influential agency and cooperates with a series of private companies in various sectors which have a common interest to use the river's resources.

Zambezi Valley Development Initiative (Zambia)

The Zambezi Valley Development Initiative (ZVDI) is a non-governmental organization and is located in the part of Barotseland that lies within Zambia's Western Province. Its mission is dedicated to improving the living conditions of people living in the Upper Zambezi Valley (primarily but not exclusively the Lozi people). It has adopted a multiple objective approach, mainly focusing on cultural heritage and education, though its programs include food security, management of wetland zones, and biodiversity in the floodplains.

4.2.7 Recommendations for further analysis

Despite delays and absence of necessary ratifications, the ZAMCOM Agreement is practically operational with incoming interim institutions and programs.

The MSIOA study has identified two areas of analysis that can be pursued in parallel in preparation of full ratification of ZAMCOM and establishing the interim ZAMCOM secretariat. These are: developing concrete procedures for cost and benefit sharing on specific regional and basin-wide investments; and, initiating practical actions of common interest that are not directly governed by the ZAMCOM agreement (the most immediate being a common hydrology/hydrometric information management systems).

Three approaches to cost and benefit sharing in support of transboundary cooperation in the Zambezi River Basin are outlined below.

Sharing cost and benefits of hydropower generation between several countries

Sharing cost and benefits of electricity generated by hydropower among multiple countries is common. Agreeing on the rules of sharing cost can provide a suitable starting point for multilateral negotiations and the aim is usually to share the yields in accordance. Hydropower is a typical case of conjunctive production with increasing returns of scale, i.e. the cost of supplying the same amount of electricity to an additional country is lower than the cost of supplying it to a previously involved country.

Shapley-Shubik (1954) outlined two fundamental principles for such arrangements:

- Equity, or in other words "equal treatment of equals"; and
- The contribution of each player depends on their own contribution to the benefits of the joint efforts.

If the benefits of the joint production efforts are increasingly high, an alternative to the Shapley-Shubik value is serial cost sharing, which depends on the equity principle and on protecting small consumers against the costs generated by larger consumers (Moulin and Shenker 1992).

Sharing costs and benefits of using water resources for multiple objectives within one country

Sharing the costs and benefits of managing water resource for multiple uses and objectives within a single country is directly linked to the application of a national water policy. Proper consideration must be given to economic development achieved through developing the hydropower, agriculture and industrial sectors, but also on safeguarding environmental sustainability and protection as well as sufficient management and distribution of domestic water supply. The Pareto optimality[23] is a desirable outcome of any cost and benefit sharing mechanism. Maximizing the objectives of one water use, with given constraints, would involve the following steps:

- Assigning a realistic monetary value to each water use is desirable and will enable comparison;
- Determining the constraints that corresponds to minimal use of water;
- Developing a model of linear programs, which will maximize (i) the sum of the objectives, and (ii) the conditions subject to the sum of constraints; and
- Solving the program.

The solution thus obtained will represent a formula for sharing water resources among different objectives while maximizing the welfare of a whole country.

Sharing costs and benefits of a watercourse when used for multiple objectives and by several countries

Sharing costs and benefits of water resource management between multiple objectives (hydropower,

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[23] Pareto optimality is an important concept in economics with broad applications in game theory, engineering and the social sciences. Given a set of alternative allocations, a change from one allocation to another that can make at least one individual better off without making any other individual worse off is called the Pareto improvement. An allocation is Pareto optimal when no further Pareto improvements can be made.

irrigation, flood protection, etc.) and among several countries can be done through a superposition of the two methods discussed above. Consideration must also be given to guaranteeing water for primary needs, and non-negotiable demands of countries upstream and downstream of the transboundary watercourse. In economic literature, the subject is well discussed in terms of cooperative game and non-cooperative game, depending on the degree to which countries collaborate.

In this case, the first step is to determine the Pareto optimality that maximizes the community welfare of all the countries sharing the Zambezi River Basin. Next, the sharing of the cooperative benefits can be considered in the form of the Shapely-Shubik value or using the serial cost sharing mechanism.

4.2.8 Concluding remarks

The framework established by the SADC Revised Protocol on Shared Watercourses strengthens transboundary cooperation in the Zambezi River Basin to the benefit of all riparian countries. The ZAMCOM Agreement, though not fully operationalized, allows for an interim secretariat and potentially activities are of interest to the entire Basin.

Many of the riparian countries already engage in bilateral cooperation, both formal and informal. National or bilateral agencies exist and though some cooperate, there is need for more interagency collaboration.

The management, collection and exchange of hydrometric/hydrologic data needs urgent strengthening across the Basin. Improving these information management systems does not require fully implemented agreements and will rely on well functioning and widespread networks of gauging stations. In addition, political and financial commitment can lead to tremendous benefits for users of the data—whether it is for planning infrastructure such as bridges or for preventing and protecting against floods.

There is fast growing interest in developing the Zambezi River's resources for multiple purposes across the Basin. Various large-scale projects in the pipeline involve the governments in the riparian countries, private sector actors as well as the international community. Appropriate procedures, programs and policies should be established to make the most from this interest to the benefit of economic development and poverty reduction.

Ratification and operationalization of the ZAMCOM Agreement would enable a platform for cooperation that secures not only the best results from managing the rivers resources, but also the most desirable benefits for all riparian countries.

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Annex

List of stakeholders consulted

Date of meeting	Institution	Purpose	Attendees
Angola			
10/09/2008	FAO/EPSMO	Discussion on relevant documentation and contacts.	Mr. Manuel Quintino
11/04/2008	DNA/GABHIC – Direcção Nacional de Águas/ Gabinete para Administração da Bacia Hidrográfica do Rio Cunene	Discussion on ZACPLAN and Strategic Plans for the Zambezi River Basin in terms of water resources (Angola perspective)	Messrs. Armindo Gomes da Silva, Manuel Quintino, Rute Saraiva, Dário Rodrigues
11/05/2008	SADC National Executive Secretary	Discussion on ZACPLAN and Strategic Plans for Zambezi River Basin in terms of water resources (SADC perspective)	Messrs. Beatriz Morais, Manuel Quintino, Rute Saraiva, Dário Rodrigues
11/05/2008	DNA – Direcção Nacional de Águas	Discussion on water supply plans for Moxico Province	Messrs. Guilherme Tavora, Rute Saraiva, Dário Rodrigues
11/05/2008	DNA – Direcção Nacional de Águas	Discussion on hydropower development plans and other related water uses for Moxico Province	Messrs. Paulo Emidio, Rute Saraiva, Dário Rodrigues
11/06/2008	MINAGRI – Ministério da Agricultura	Discussion on the National Irrigation Master Plan (Irrigation Schemes)	Messrs. Jorge David, Rute Saraiva, Dário Rodrigues
11/07/2008	MINERG – Ministério da Energia	Discussion on ZacPlan and other related documentation for the Zambezi River Basin	Messrs. José Salgueiro, Dário Rodrigues
11/18/2008	MINERG – Ministério da Energia	Discussion on Hydropower Development Plans for Moxico Province	Messrs. Francisco Talino, Dário Rodrigues
12/02/2009	MINAGRI – Ministério da Agricultura	Update data for current situation and identified projects	Mr. Dos Santos
12/03/2009	Ministério de Geologia e Minas	Update data for mining sector	Mr. Buta Neto
12/03/2009	DNA – Direcção Nacional de Águas	Wrap-up meeting	Mr. Lucrécio Costa
Botswana			
05/16/2008	Department of Water Affairs	Discussion of documents and contacts for MSIOA	Mr. Ontlogetse Dikgomo
05/29/2008	FAO	Request for documents on Agricultural projects in Botswana	Mr. Aidan Gulliver
09/12/2008	Environmental Consultant	Request for documentation regarding tourism development in Zambezi River Basin	Mr. Jon Barnes
Malawi			
06/12/2008 06/13/2008	Ministry of Irrigation and Water Development	Water resources, hydrology of Shire River and Lake Malawi/Niassa/Nyasa and irrigation demand and development plans	Messr. S. Mainala, A. Chirwa, P. Kaluwa, Maweru and W. Mikuwa

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List of stakeholders consulted *(continued)*

Date of meeting	Institution	Purpose	Attendees
06/09/2008 06/19/2008 06/20/2008	Electricity Supply Corporation of Malawi	Hydrology of hydropower plants	Messr. M. Chisale, D. Chapalapata, E. Msiska and M. Gondwe
06/17/2008	Malawi Energy Regulatory Authority	Energy policies and electricity tariff	Dr. C. Kafumba, Mrs. E. Potani,
06/25/2008	Mining Department	Mining energy demand	Mr. P. Chilunguma
06/10/2008	Illovo Sugar Company	Irrigation water and energy demand	Mr. E. Majamanda, and the Agriculture Manager
09/30/2009	Ministry of Natural Resources, Energy and Environment	Update of capital costs for HPP	Mr. Kaunda, Director of Planning
Mozambique			
05/20/2008	National Directorate for Agricultural Services	Irrigation schemes	Messr. Aurélio Nhabetse, José Almeida
05/21/2008	Unidade Técnica de Implementação dos Projectos Hidroeléctricos	Hydroelectric Projects Implementation Unit (Plus)	Mr. Sérgio Elísio
05/23/2008	Ministry of Tourism	Tourism	Mr. Mohamed Haron
05/23/2008	DNA – Direcção Nacional de Águas	Water resources management	Messr. Delário Sengo and Hilário Pereira.
05/27/2008	Ministry of Mineral Resources	Mineral resources	Messr. Eduardo Alexandre, Antönio Cumbane
05/27/2008	Zambezi Valley Spatial Development Initiative	Zambezi Valley Management Unit	Mr. Eduardo T. França
05/29/2008	Centro de Promoção de Investimentos	Investment Promotion Centre	Mr. Mussa Usman
11/03/2008	DNA – Direcção Nacional de Águas	Water resources management/ZAMCOM	Messr./Mmes. Suzana Saranga, Belarmino Chivambo, José Malanço, Hilário Pereira
11/04/2008	Instituto Nacional de Gestão de Calamidade	Floods in Zambezi River Basin	Mr. Pedro Tomo
11/04/2008	National Directorate for Agricultural Services	Irrigation schemes in Zambezi River Basin	Messr. Onassis Oliviera, Marcelo Chaquisse, Aurélio Nhabetse
11/05/2008	Gabinete de Promoção do Zambezi	Zambezi Valley Management Unit	Messr. Sergio Vieira, Ambrosio Da Fonseca, Amindo Fanhiça, and others
11/06/2008	Hidroeléctrica de Cahora Bassa	Electricity Production Unit	Messr. Gildo Sibumbe, Gustavo Cornelius Jessen, and others
11/07/2008	ARA-Zambeze	Development of Mozambican part of Zambezi River Basin	Messr. Manuel Malaze, Carlos Fenhane
09/24/2009	INGC/CENOE	Floods in lower Zambezi	Mr. Bonifacio Antônio
09/24/2009	UTIP	Update studies for Mphanda Nkuwa	Mr. Sérgio Elisio
09/24/2009	World Bank/Colorado State University	Climate changes and the Zambezi River Basin	
09/24/2009	Hidroeléctrica de Mphanda Nkuwa	Update studies for Mphanda Nkuwa Dam	Mr. Alexandre Ferreia, Mrs. Madalena Dray
09/25/2009	RMSI	Floods in Mozambique/Malawi	Mr. B. Radha Krishna Murthy
09/25/2009	World Bank	Energy economy	Mr. Reto Theonen

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List of stakeholders consulted *(continued)*

Date of meeting	Institution	Purpose	Attendees
Namibia			
05/07/2008	Ministry of Agriculture, Water and Forestry	Discussion on documents for MSIOA	Mr. T. Basson (Deputy Dir. Engineering Services) Mr. P. Lieberberg (Engineer)
05/08/2008	Namibia Development Corporation	Discussion on irrigation projects in Caprivi Region in Zambezi River Basin	Mr. P. de Wet (Agricultural Economist)
05/08/2008	Ministry of Agriculture, Water and Forestry	Discussion on documents for MSIOA	Mr. A. Nehemia (Deputy Permanent Secretary Water Affairs) Mr. S. Luyanga (Development Planner)
06/03/2008	Ministry of Agriculture, Water and Forestry	Discussion on documents for MSIOA	Dr. S. de Wet (Director Water Resources) Mr. P. Liebenberg (Agricultural Engineer)
06/04/2008	Ministry of Agriculture, Water and Forestry	Collection of FAO report on SADC Agricultural plans	Mr. T. Basson (Deputy Director)
Tanzania			
05/24/2008	WWF Tanzania	Songwe River Catchment studies	Mr. Leodgard Haule (National Coordinator WWF)
06/03/2008	TANESCO	Hydropower Rumakali Feasibility Study	Messr./Mmes. Katyega, Maneno John (Principal Research Engineer)
06/04/2008	World Bank, Dar es Salaam	World Bank involvement in the Shire River – Lake Malawi/Niassa/Nyasa subbasin	Ms. Jane Kibassa
06/04/2008	World Bank, Dar es Salaam	Agriculture and rural development	Mr. Henry Gordon (Senior Sector Economist)
06/05/2008	Ministry of Water and Irrigation	Water resources management in the Shire River – Lake Malawi/Niassa/Nyasa subbasin	Mr./Ms. A. Mwitagila
06/05/2008	Ministry of Water and Irrigation	Water policy issues	Mr./Ms. J. Mihayo (Assistant Director)
08/24/2008	Ministry of Water and Irrigation	Water Use in the Shire River – Lake Malawi/Niassa/Nyasa subbasin	Mr./Ms. A. Mwitagila
11/06/2009	Ministry of Water and Irrigation	Update data for irrigation sector	Director of Irrigation and Technical Services
11/06/2009	Ministry of Energy and Minerals	Update information for Rumakali and Songwé HPP	Messr. Bashir Mrindoko, Erasto Simon
09/19/2008	Environmental consultant	Request for documentation regarding tourism development in Zambezi River Basin	Mr. Jon Barnes
09/19/2008	IECN	Request for documentation regarding tourism development in Zambezi River Basin	Mrs. Julianne Zeidler
11/03/2009	Ministry of Water and Irrigation	Update current situation and identified projects in agriculture	Messr./Mmes. Abraham Nehemia, Matthew Mushabati, Florence Sibanda, Liedenberg

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List of stakeholders consulted *(continued)*

Date of meeting	Institution	Purpose	Attendees
23/05/2008	Ministry of Water and Irrigation	Irrigation policy	Mr. P.F. Kweka (Zonal Irrigation Engineer)
Zambia			
04/01/2008	World Bank	Introductory meetings with the World Bank team	Messr./Mmes. Len Abrams, Marcus Wishart, Rimma Dankova
04/02/2008	ZAMCOM	Meeting of Committee of Senior Officials Chisamba	Senior Officials ZAMCOM
04/06/2008	ZRA	Site visit to Kariba Dam	Mr. John Bosco
04/07/2008	Euroconsult Mott MacDonald	IWRM Strategy and Implementation Plan for the Zambezi River Basin	Dr. Inyambo Nyumbu
04/08/2008	University of Zambia, Hydrogeological Department	Presentation of project and data collection	Prof. Imasiku Nyambe
04/08/2008	ZRA	Presentation of project and data collection	Dr. Michael Tumbare (Chief Executive), Mr. Clement Mukosa (Chief Engineer), Mr. Wilson Sakala (Hydrologist), Mr. Samuel Mwale (Modeling Technician)
04/08/2008	Zambezi Action Plan Project 6 (ZACPRO6):	Presentation of project and data collection	Dr. Zebediah Phiri (Project Manager), Dr. Jefter Sakupwanya (Water Resources Expert), Ms. Leonnisah Munjoma (Communications Specialist), Ms. Karin Gullstrand (Associate GIS Expert)
04/09/2008	Ministry of Tourism, Environment and Natural Resources	Presentation of project and data collection	Messr./Mmes. Godwin Gondwe, (Chief Environmental Management Officer), Frederick Mulenga (Provincial Forestry Officer), Mr. Kanyemba (Agronomist), Mr. Mwase Phiri (ref. National Irrigation Strategy and Plan)
04/09/2008	World Bank	CADP	Mr. Alex Mwanaksabe (Agricultural Specialist)
04/09/2008	Department of Water Affairs	ZAMCOM & hydrology in Zambia	Messr. Adam Hussen (Director), Antony Mporokoso, (Principal Hydrologist)
04/10/2008	World Bank	Tourism sector in the Basin, biodiversity and water resources management	Mr. Jean-Michel Pavy
04/11/2008	Zambia National Farmers' Union	Presentation of project and data collection on crop budgets	Mr. John F.W. Fynn (Technical Assistant)

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List of stakeholders consulted *(continued)*

Date of meeting	Institution	Purpose	Attendees
04/15/2008	ZESCO	Presentation of project and data collection	Messr./Mmes. Alvin Monga (Director, Engineering Development), Romas Kamanga (Senior Engineer), Elenestina Mwelwa (Hydrologist)
04/16/2008	WWF Zambia	Presentation of project and data collection	Mr. James Phiri (Country Manager)
04/17/2008	Ministry of Energy and Water Development, Water Board	Presentation of project and data collection	Mr. Andy Mondoka
04/17/2008	Ministry of Energy and Water Development	Presentation of project and data collection	Messr. Ben Chundu (Director of Planning), Mundu Mwila (Planner)
05/27/2008	World Bank	Irrigation in Kafue River Basin	Mr. Timothy Stephens
06/02/2008	Farmer	Visit of sugar cane farm in Kafue River Basin	Mr. Nick Patterson
06/02/2008	Farmer	Visit of Kaleya smallholders company	Messr./Mmes. Solomon Njobvu (Director), Rama Varma (accountant)
06/10/2008	World Bank	Obtain tourism studies and information	Mr. Jean-Michel Pavy
06/11/2008	WWF and Nature Conservancy	Wetlands and environment in Zambezi River Basin	Mr. David Harrison
09/17/2009	ZESCO	Operation of Itezhi Tezhi and the Kafue Flats	Mr. Romas Kamenga
09/17/2009	Ministry of Agriculture	Review and validation of data on irrigation: current situation and identified projects	Mr. Sikuleka
09/17/2009	ZESCO	Review pricing of electricity	Ms. Claire Limbwambwa
Zimbabwe			
05/15/2008	World Bank		Mr./Ms. Chidawanyika
05/16/2008	FAO		Mr. Martin Adger
05/16/2008	FAO		Ms. Aubrey Harris
05/16/2008	SARDC-IMERCSA		Mr. Egline Tawuya
05/16/2008	University of Zimbabwe, Department of Soil Science		Mr. Emmanuel Manzungu(Senior Lecturer)
05/16/2008	Ministry of Agriculture, Mechanisation and Irrigation Development		Mr. T. Chipunza (Acting Chief Agricultural Economist)
			Mr. Shepherd Mazani (Senior Agricultural Economist)
05/20/2008	Ministry of Water Resources and Infrastructure Development		Mr. Chitsiko (Permanent Secretary)
			Eng. Mawere (Deputy Director)
05/21/2008	Ministry of Energy and Power Development		Eng. Munodawafa (Director, Department of Power)

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List of stakeholders consulted *(continued)*

Date of meeting	Institution	Purpose	Attendees
05/21/2008	Ministry of Water Resources and Infrastructure Development		Dr. S.S. Mlambo (Permanent Secretary), Dr. E. Chadenga (Director), Dr. Zawo (Acting Deputy Director), Z. Shumba (Chief Engineer for Midlands Province), Hakata (Accounting Officer for the department), T. Zvavamwe (Acting Chief Agricultural Economist)
05/22/2008	Ministry of Water Resources and Infrastructure Development		Messr./Mmes. Dr. E. Chadenga (Director), N. Mufute (Irrigation Engineer), T. Zvavamwe (Acting Chief Agricultural Economist)
05/23/2008	Ministry of Environment and Tourism		Ms. Elizabeth Sangarwe (Permanent Secrtary)
05/28/2008	Zimbabwe National Water Authority (ZINWA) Ministry of Water Resources and Infrastructure Development		Messr./Mmes. E.K. Madamombe (Data and Research Manager ZINWA), Marumbwa (GIS Specialist ZINWA)

THE WORLD BANK GROUP
1818 H Street, N.W.
Washington, D.C. 20433 USA