

IMPLICATIONS OF CONVERTING LAKE KARIBA TO MULTIPURPOSE DAM IN VIEW OF INCREASED DEMAND FOR WATER IN ZAMBIA AND ZIMBABWE

by

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B.Eng (Agric)

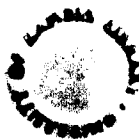
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A Dissertation submitted to the University of Zambia in partial fulfillment of the requirements for the Post-Graduate Diploma in Integrated Water Resources Management



The University of Zambia

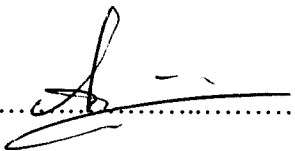
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Declaration

I, Pherry Chimwaya Mwiinga, do hereby declare that this dissertation represents my own work, and that it has not previously been submitted for a Post-graduate Diploma at this University or any other University.

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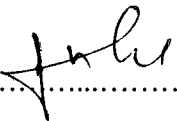
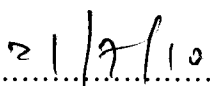
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Approval

This dissertation of Pherry Chimwaya Mwiinga has been approved as partial fulfillment of the requirement for the award of the Post-graduate Diploma in Integrated Water Resources Management (IWRM) by the University of Zambia.

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Abstract

The Kariba Reservoir is one of the largest man-made lakes in the world. It was created after the impoundment of the Zambezi River at the head of the Kariba Gorge primarily to provide hydro-electric power for mining and industrial development in the then Federation of Rhodesia and Nyasaland (which is now Zambia, Zimbabwe and Malawi). Impoundment started in 1958, filling the lake for the first time in August 1963. Thousands of people and their livestock were displaced as their dwellings and fields got submerged, giving way to the 180.6 km³ Kariba Lake covering over 5,000 km² of the Zambezi Valley. Paradoxically, extreme poverty and hunger have become endemic among the riparian local communities in Zambia and Zimbabwe.

This study looks at the implications of converting the Kariba from a single to a multipurpose reservoir with a view to expand its contribution to meeting Goal Number 1 of the Millennium Development Goals (MDGs), namely, *Eradicate extreme poverty and hunger by 2015*. The research involved the collection of extractive water usage data from the Zambezi River riparian interests between Kazungula on the Zambia/Zimbabwe/Botswana tripartite border point and the Kariba Dam, and simulating hydropower generation at Kariba under average hydrologic conditions as well as current and projected installed capacities. The simulation procedure was accomplished with the use of the HEC-3 Reservoir System Analysis for Conservation computer programme.

Data collected from the field by way of personal interviews and pumping / usage estimations indicate that an estimated total of 2,540,052 m³day⁻¹ (approximately 29 m³/s) is abstracted from the Zambezi River and Lake Kariba between Kazungula and Kariba Dam for non-hydropower usage. This figure comprises abstractions of 165,167 m³day⁻¹ on the Zambian side and 2,374,885 m³day⁻¹ on the Zimbabwean side. For purposes of assessing the impact of extractive water usage on hydropower generation at Kariba Dam in the short to medium term, this study considers an abstraction level of 71 m³/s comprising current usage (as indicated above) and the 2020-25 planned abstraction. The simulation results indicate an insignificant impact on hydro-power generation at Kariba Dam.

The study therefore concludes that multiple usage of Lake Kariba does not impinge on its original single-purpose design for hydropower generation at Kariba Dam. In this regard, the study recommends taking full advantage of the extensive Lake Kariba waters to prop up irrigated agriculture in order to contribute to the eventual attainment of MDG Number 1 among the riparian communities and beyond.

Dedication

*To my Dear Wife, Bwalya and our Children:
Beenzu, 'Cleopatra', Cholwe, Chaabo, Kateule and Mwaka*

... your rare combination of excellence and humility has always inspired me!

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First and foremost, I wish to extol my God and Creator for His mercies that are 'new every morning.'

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The magnanimity of the Danish International Development Agency (DANIDA) in sponsoring this historic post-graduate programme in IWRM at the University of Zambia cannot be overemphasized, for, without it, I might not have had the opportunity to pursue this course in my home-country.

I wish to also acknowledge the input and assistance of Messrs Chrispin Namakando and Samuel Mwale of Zambezi River Authority who respectively facilitated in the field surveys that rewarded this study with the primary data and the simulation studies with the HEC-3 computer model.

Special thanks also go to my Employers, the Zambezi River Authority for the permission to not only participate in the coursework but also use data collected and processed on the Authority's time, resources and cost. Engineers CFG Mukosa and EM Siamachoka – Director and Senior Manager, respectively (Water Resources & Environmental Management Department) were extremely helpful in this regard.

Lastly, but by no means the least, I wish to thank my dear wife, Bwalya and 'The Clan' for their moral support and patience during the long hours spent with books in their stead.

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List of Abbreviations and Acronyms

DANIDA	Danish International Development Agency
FNDP	<i>Fifth National Development Plan</i>
HEC-3	Hydrologic Engineering Centre – Reservoir System Analysis for Conservation, version 3
IWRM	Integrated Water Resources Management
MDG(s)	Millennium Development Goal(s)
SADC	<i>Southern Africa Development Community</i>
SADC-WD	SADC – Water Division
USACE	United States Army Corps of Engineers
ZACPLAN	Zambezi River Action Plan
ZACPRO 6.1	ZACPLAN Project 6 Phase 1
ZACPRO 6.2	ZACPLAN Project 6 Phase 2
ZAMCOM	Zambezi Water Course Commission
ZRA	Zambezi River Authority
ZINWA	Zimbabwe National Water Authority

CHAPTER 1: INTRODUCTION

1.1 Background

The Kariba Reservoir is one of the largest man-made lakes in the world. It was created after the impoundment of the Zambezi River at the head of the Kariba Gorge primarily to provide hydro-electric power for mining and industrial development in the then Federation of Rhodesia and Nyasaland (which is now Zambia, Zimbabwe and Malawi). Impoundment started in 1958, filling the lake for the first time in August 1963. Thousands of people and their livestock were displaced as their dwellings and fields got submerged, giving way to the 180.6 km³ Kariba Lake covering over 5,000 km² of the Zambezi Valley. Paradoxically, extreme poverty and hunger have become endemic among the riparian local communities in Zambia and Zimbabwe (Zambezi River Authority, 1997).

However, initiatives to ameliorate the social and economic welfare of the riparian rural communities have intensified in the recent past. For example, the Zambezi River Authority – a corporate body owned by the governments of Zambia and Zimbabwe mandated to administer the Kariba Complex (Kariba Dam and attendant infrastructure) and the stretch of the Zambezi River shared by the two countries in the context of the ZRA Act of 1987 (Act No. 17 and 19 of the Republics of Zambia and Zimbabwe, respectively) – is implementing various development projects among the displaced communities in the Valley under the Zambezi Valley Development Fund (Zambezi River Authority, 1997), sponsored by various donors. Zesco Ltd, the Zambian power utility firm, has also been implementing similar projects under its social component of the World Bank-supported Power Rehabilitation Project. As most of these programmes are agro-based, the use of the Zambezi River / Lake Kariba waters for sustainable implementation of irrigation projects is the target. Besides, an increasing number of commercial entities have set up or are setting up irrigation and other water-using ventures such as hotels/lodges and fishing industries.

A study by the World Commission of Dams on Lake Kariba (2000) projects a combined irrigable area around Lake Kariba to 17,000 ha, which, assuming an annual

average water consumption of 1750mm, would require about $300,000 \times 10^3 \text{ m}^3$ of water per year ($9.5 \text{ m}^3/\text{s}$).

Beyond the immediate environs of the Zambezi River and Lake Kariba, plans are underway to construct inter-basin water transfer schemes to abstract considerable volumes of water from the Zambezi River to meet increasing demand in other basins. Botswana, for example, is planning to abstract some $16 \text{ m}^3/\text{s}$ of water from the Zambezi under the proposed Chobe/Zambezi Water Transfer Scheme expected to be commissioned by 2022 (Republic of Botswana, 2009). Probably of similar magnitude is the proposed Bulawayo-Matabeleland-Zambezi Water Supply Project which is also in its feasibility stage (Euroconsult Mott MacDonald, 2007).

From the foregoing, it is quite evident that demand for the Zambezi water is increasing both within the riparian zones and beyond.

This study is therefore intended to contribute to the reservoir of knowledge and information for present and future development processes in the Zambezi Valley between Zambia and Zimbabwe. Its central focus is the assessment of the implication of converting the use of the Lake Kariba water from single (that is, hydro-power generation) to multipurpose in view of not only the increasing demand for water in the area but also for national strategic reasons.

By definition, a multi-purpose reservoir is one that is designed to serve two or more functions, the most common of which are:

- Irrigation;
- Water supply;
- Flood control;
- Navigation; and
- Recreation

The significant difference between the operating purposes, including power, is the requirement for release from the reservoir and the consequent impact on reservoir

levels. Typical requirements imposed on a reservoir by the prospective user relate to one or all of the following:

- **Power:** the preferred flow release is relatively uniform; hence reservoir levels are drawn down in the dry season, with refill during the wet season. Reliability of supply is generally high. Since power and energy is the ultimate product, head and hence reservoir level is also important and the tendency is hence to keep reservoir levels as high as possible (subject to firm energy and dry storage use)
- **Irrigation:** reservoir levels are unimportant (neglecting cases where irrigation water is drawn by gravity or pumped from reservoir upper levels – very common for storage reservoirs as opposed to diversion dams). Supply reliability not generally as high as for power. Unlike power, required flow release tends to be seasonally very variable – zero at times. With no concern for head and an inherently higher value for water, reservoir drawdown can be much longer.
- **Water Supply:** normally the highest value water use, no concern over reservoir levels (assuming supply point is downstream) – otherwise similar to power, requiring high reliability and fairly uniform flow release.
- **Flood Control:** unlike all other problems, in that flood control requires storage above a normal or target level, i.e., for power, irrigation or water supply under ideal conditions, the reservoir will be maintained at a high level – the reverse applies for flood control. Storage ability is crucial and downstream release over the longer term is unimportant – neglecting the overriding objective of reducing normally short term (hours/day) release under flood conditions.
- **Navigation:** operation for downstream navigation is similar to irrigation or water supply. For navigation on the reservoir the common requirement is to maintain levels relatively constant.
- **Recreation:** covers a broad spectrum including maintenance of acceptable environmental conditions. One class of requirements call for reservoir levels to hold more-or-less constant, i.e., similar to those of a natural lake; the other covers monitoring satisfactory downstream flow release (riparian flow) – also typically dictated by natural conditions. As a class, recreational requirements are unique in generally calling for the reservoir to perform as a lake, i.e., with very little use of storage, this is therefore in sharp conflict with most of the other uses.

1.2 Problem Statement

With increasing population, demand for water to meet various socio-economic needs has increased. The huge volume of water in the Kariba Reservoir could greatly *contribute to meeting the rising demand. The question is what would be the implication of diversifying the water usage in Lake Kariba on hydropower generation at Kariba Dam?*

1.3 Aim

The aim of the study is to meet the increasing demand for water by diversifying usage of the Kariba waters for wealth creation and poverty reduction among riparian communities.

1.4 Objectives

The objectives of this study are as follows:

- 1) To quantify water demands from the Zambezi River and Lake Kariba for extractive users in Zambia and Zimbabwe
- 2) To assess the impact of water abstraction from the Zambezi River and Lake Kariba on hydropower generation
- 3) To develop a scenario-based water balance model vis-à-vis hydropower generation for the Zambezi River reach shared by Zambia and Zimbabwe.
- 4) To design a water allocation policy for Lake Kariba for users other than hydropower

1.5 Rationale

Zambia and Zimbabwe have both domesticated the United Nations Millennium Development Goals, including Goal Number 1 which states: “To eradicate extreme poverty and hunger.” In this regard, it has been realized that agriculture plays a pivotal role in wealth creation and also that water is a central factor in revolutionizing agriculture for the attainment of food security and poverty alleviation (Nyambe and Feilberg, 2009).

According to the recently concluded Southern Africa Development Community – Water Division (SADC-WD) / Zambezi River Authority’s Zambezi River Action Plan Project (ZACPRO) Number 6.2 (Euroconsult Mott MacDonald, 2007), Zambia and

Zimbabwe, among other Basin countries, have prioritized agriculture as the main vehicle to attaining MDG Number 1. In the case of Zambia, for example, the Zambia Vision 2030 and the Fifth National Development Plan (FNDP) place (irrigated) agriculture at elevated priority levels as the engine for guaranteeing food security, reduction in food imports, export of surplus food and other high value crops, thereby ensuring accelerated economic growth and employment creation. Although irrigation development in Zimbabwe seems to have stagnated in the last 10 years or so, relatively large schemes (e.g. Dande) have been prepared and may get off the ground in the next 10 years. Meanwhile, most of the tributary rivers where the development potential is concentrated experience very low or no streamflow in the dry season (even in average years) when irrigation water demand is highest and other needs must also be met (*Ibid*).

Diversifying the use of the Lake Kariba waters could therefore provide the much needed source of water to meet the increasing demand. There are presently no mechanisms for allocating water from the Zambezi River and Lake Kariba for uses other than hydropower.

CHAPTER 2: LITERATURE REVIEW

Probably the first attempt at estimating the impact of extractive usage of water from the Zambezi River / Lake Kariba is found in a study by Zimconsult (1995) in which a thorough economic assessment of water usage was done in the context of an attempt to design a fee and tariff structure for the Zambezi River Authority. During this study, water usage data collected for the larger part of the catchment's extractive water users indicated that less than 1% of the water available for energy generation even in drought years was actually abstracted. In consideration of this and other economic factors, the study recommended an indirect charge on abstractors through the national taxation arrangements as well as direct charges for actual water utilized by the power utilities at Kariba Dam.

The Zambezi River Authority (1997) also undertook a study code-named 'Kariba Dam's Operation Noah Re-launched' through which a 'reparation and rehabilitation' programme was launched for the displaced communities of the pre-flooding era of the Zambezi Valley. To date, a number of developmental projects have been implemented in the area, some of which involve the usage of the Kariba water for agriculture. Zesco Ltd too – under its World-Bank funded Power Rehabilitation Project – did implement a number of community projects on the Zambian side, particularly in regard to supplying electricity to the area.

A comprehensive strategic plan for the Zimbabwean side of Lake Kariba was developed in 1998 (Kariba Lakeshore Combination Master Plan Authority, 1998) highlighting both water-based and terrestrial developmental projects that were to be undertaken in various districts riparian to the Lake Kariba.

The World Commission on Dams (2000) carried out a scoping and case study of the Kariba Dam as one of the ten dams identified worldwide for such a study that would contribute to the international debate on the development effectiveness of large dams. Some of the lessons learnt from the study included the following:

- Hydroelectric schemes may have far more implications than just the production of electricity;
- Major hydropower projects can lead to continuously low tariffs, with major benefits for the residential, commercial and industrial consumers;
- In dam projects, cases of involuntary resettlement require detailed planning and the full participation of the affected people in the planning process. In addition, the planning process must be carried out well ahead of resettlement process and must ensure adequate infrastructure in the new areas of settlement to minimize the trauma of resettlement for the displaced people by the dam. As far as possible, the displaced people must be equally or more comfortable in their new settlement areas than their areas of settlement in the dam basin; and
- As shown in the case of the Kariba Dam, a number of initiatives (trust funds, targeted development projects) can be considered for addressing some of the unsettled issues inherited from the past.

The study also observed that the existing irrigation schemes in Zimbabwe, that is, Charara and Gatshe Gatshe consume a total of around 0.0087 % of the Kariba Dam's live storage (64.5km^3), a situation that is of no consequence to the availability of water for electricity. The study further projected the combined irrigable area around Lake Kariba to 17,000 ha, which, assuming an annual average water consumption of 1750mm, would require about $300,000 \times 10^3 \text{ m}^3$ of water per year ($9.5 \text{ m}^3/\text{s}$), representing a mere 0.47% of the total live storage of Lake Kariba – still an insignificant amount that was unlikely to affect power generation (World Commission on Dams, 2000).

CHAPTER 3: STUDY AREA

3.1 The Zambezi River

The Zambezi River, shared by eight Southern African countries, is one of Africa's four major rivers with a total basin area of $1.4 \times 10^6 \text{ km}^2$ (Figure 1). The contributions of the eight countries to the basin runoff are: Zambia, 40.7%, Zimbabwe 16%, Angola 18.2% Mozambique 11.4%, Malawi 7.7%, Botswana 2.8%, Tanzania 2% and Namibia 1.2%. Figure 1 below shows the extent of the Zambezi River Basin as well as the location of the Lake Kariba on the border between Zambia and Zimbabwe, which is the area of interest in this study.

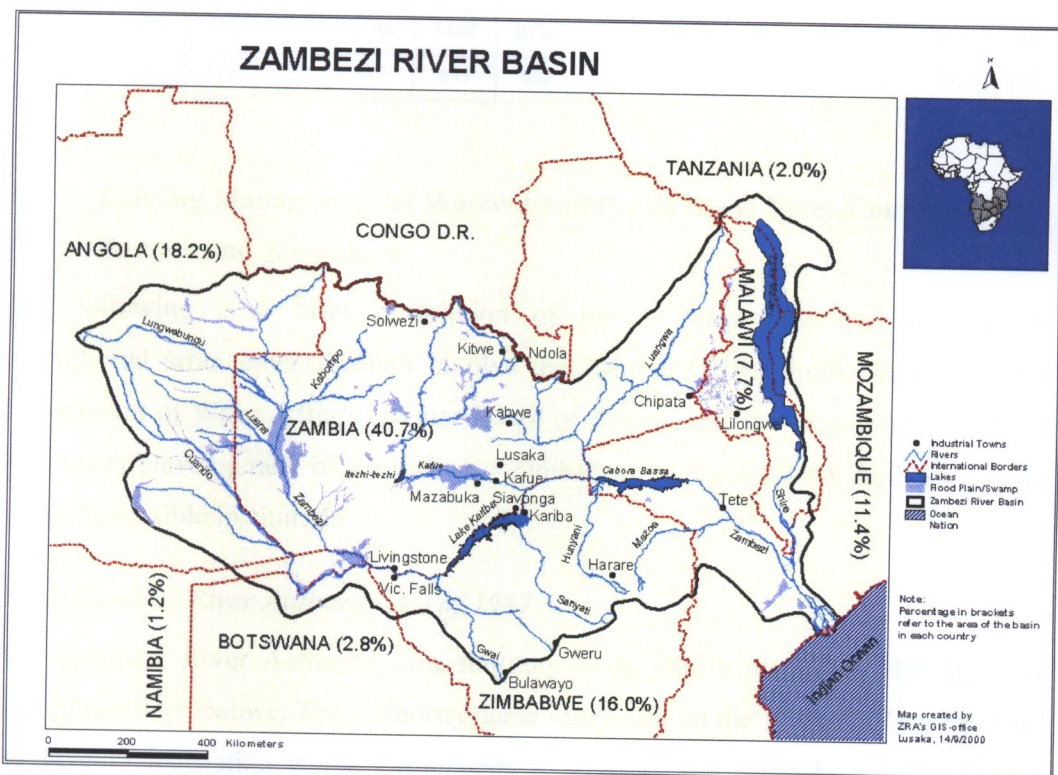


Figure 1: The Zambezi River Basin, showing the Position of Lake Kariba on the Border between Zambia and Zimbabwe and Riparian-state Runoff Contributions to the Basin

3.2 The Zambezi River Flows

Average flows of the Zambezi River at the oldest station near the Victoria Falls for the period 1907 – 2008 are quoted in m^3/s in Table 1 below. These figures give a

general picture of the variation of discharges at the point of entry into the section of the Zambezi River common to Zambia and Zimbabwe.

The river mean annual flow at this station is 1,053 m³/s (Zambezi River Authority, 2009) and the Coefficient of Variation (C_v) of the flows at Victoria Falls is estimated to be 40%.

Table 1: Zambezi River Monthly Average Flows at Victoria Falls (1907 – 2008)

Flow (m ³ /s)	Month											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Mean	261	264	395	642	1055	1919	2716	2345	1473	768	467	337
Max	479	541	776	1296	5484	8720	7610	5297	3628	1770	914	610
Min	116	118	199	319	443	602	784	569	341	281	220	161

3.3 Existing Management of Water-use of the Zambezi River Common to Zambia and Zimbabwe

The following is a brief description of the existing water-use management institutional arrangements which involve the Zambezi River Authority (ZRA), the Department of Water Affairs / Water Board of Zambia and the Department of Water Resources Development of Zimbabwe / Zimbabwe National Water Authority as the main responsible institutions.

3.3.1 Zambezi River Authority Act of 1987

The Zambezi River Authority is a statutory body jointly owned by the States of Zambia and Zimbabwe. The Authority came into being on the 1st day of October 1987 by parallel legislation in the Parliaments of Zambia and Zimbabwe following the reconstitution of its predecessor, the Central African Power Corporation.

The Republics of Zambia and Zimbabwe are desirous of achieving the greatest possible benefit from the efficient utilisation of the abundant waters of the Zambezi River for the production of electric energy and for any other mutually beneficial purpose for the economic, industrial and social development of the Contracting States. The Authority's *raison d'être* is to ensure the effective use of the waters and other

resources of the Zambezi River common to the borders of the two States (Zambezi River Authority, 2005).

ZRA is governed by a Council of Ministers consisting of four members, two as Ministers in the Government of the Republic of Zambia and the other two as Ministers in the Government of the Republic of Zimbabwe. The Ministers designated by the two Governments to be members of the Council are those for the time being holding portfolios of Energy on the one hand, and Finance on the other (Ibid).

In terms of the ZRA Acts, the Council of Ministers gives direction to the Authority as will ensure the most efficient use of the Zambezi River and its installations. In this regard the Council may make rules prescribing anything which, in the opinion of the Council, is necessary or convenient to be prescribed for the better exercise of the functions of the Authority. The functions of the Authority are as set out in the schedule to Zambezi River Authority Acts Nos. 17 and 19 of 1987 of Zambia and Zimbabwe, respectively (*Ibid*).

3.3.2 Zambia Water Act of 1949, Draft Water Resources Management Bill of 2005 and the National Water Policy of 2010

Administration of the development and utilization of the water resources of Zambia is enshrined under the Water Act (Chapter 312) of 1949. The Act defines, *inter alia*, the ownership, control and use of surface water resources in Zambia. The Act also provides for the establishment of a Water Board whose responsibility is to administer the Water Act in respect of issuance of water rights. Section 3 of the Act however, provides for the exclusion of the Western Province, the Zambezi River, the Luapula River and that portion of the Luangwa River which constitutes the boundary between Zambia and Mozambique.

As of July 2007, the Water Act was however, in the process of being repealed to give way for the enactment of the Water Resources Management Bill of 2005. The Draft Bill provides for the establishment of a Water Resources Management Authority, catchment and sub-catchment councils whose primary role is the provision of equitable, reasonable and sustainable management and utilization of the water

resources of Zambia. The Draft Bill also provides for equitable and sustainable utilization of shared watercourses in recognition and implementation of various treaties, conventions and agreements, including the revised SADC Protocol on Shared Watercourses (2000).

Section 118 of the Draft Bill provides for the establishment of institutions to implement any such bilateral or multilateral agreements with any foreign state or government relating to any shared watercourse (Section 116), and in particular to (a) investigate, manage, monitor and protect the water course; (b) foster regional cooperation over the watercourse; (c) acquire, construct, alter, operate or maintain any works; or (d) allocate, use and supply water from the watercourse. In this regard, the Bill provides for particular recognition of existing trans-boundary water resource management arrangements through the Zambezi River Authority (Section 119) (Government of the Republic of Zambia, 2007).

As a forerunner to the imminent enactment of the Zambia Water Resources Management Bill, the Government of the Republic of Zambia adopted the National Water Policy in February 2010. The National Water Policy 2010 provides for the holistic management of the country's surface and groundwater resources through an integrated approach. The Policy also stipulates the country's position and role on various international and regional conventions and protocols on water resources management and development, including the Revised SADC Protocol on Shared Watercourses and the ZRA Act. The Policy provides a direction and framework for management, development and utilization of water resources in Zambia (Government of the Republic of Zambia, 2010)

3.3.3 Zimbabwe Water Act of 1998

Administration of the development and utilization of the water resources of Zimbabwe is enshrined under the Water Act (Chapter 20:24) of 1998 which provides, among other things, the establishment of catchment and subcatchment councils under the general supervision of the Zimbabwe National Water Authority (ZINWA). ZINWA, established by section 3 of the ZINWA Act (Chapter 20:25) is involved in the construction of dams and supplies water to most local authorities in the country.



Through the water act it controls and monitors all water pollution activities occurring throughout the country.

Relating to ‘Savings in relation to Zambezi River Authority’, Section 120 of the Zimbabwe Water Act of 1998 states as follows:

“Notwithstanding this Act, the Zambezi River Authority referred to in Section 4 of the Zambezi River Authority Act (Chapter 20:23) may continue to perform its functions and exercise its rights in relation to the use, extraction and storage of water in or from the Zambezi river in respect of the Kariba dam, the Kariba hydro-electric scheme and any other undertaking which are conferred upon it by or in terms of that Act.”

The Zimbabwe National Water Authority is a statutory corporation charged with the operational aspects of what was part of the work of the Department of Water Development. With the establishment of ZINWA, the development and management of the national water resources is the responsibility of the Authority whilst the policy making and regulatory functions remain the responsibility of the Government in the Department of Water Development. The Authority operates on a commercial basis except in respect of certain non-commercial functions for which levies are raised from certain water consumers (Government of the Republic of Zimbabwe, 1998).

3.3.4 Revised SADC Protocol on Shared Watercourse Systems

The Protocol on Shared Watercourse Systems in the Southern African Development Community (SADC) Region (1995), which entered into force on 29th September 1998, was revised at a summit of Heads of State or Government, or duly authorised representatives, of SADC Member States, held in Windhoek, Namibia, on 7th August 2000. As of July 2001, Zambia and Zimbabwe were among the ten SADC countries that had ratified the 1995 Protocol. Others were: *Botswana, Lesotho, Malawi, Mauritius, Namibia, South Africa, Swaziland and Tanzania*. The Revised Protocol signed by all the fourteen SADC member states, had been ratified by three member states as of June 2001 (Ramoeli, 2002).

The overall objective of the Protocol is to foster closer cooperation for judicious, sustainable and co-ordinated management, protection and utilisation of shared watercourses and advance the SADC agenda of regional integration and poverty alleviation. In order to achieve this objective, the Protocol seeks to:

- (a) Promote and facilitate the establishment of shared watercourse agreements and Shared Watercourse Institutions for the management of shared watercourses;
- (b) Advance the sustainable, equitable and reasonable utilisation of the shared watercourses;
- (c) Promote a co-ordinated and integrated environmentally sound development and management of shared watercourses;
- (d) Promote the harmonisation and monitoring of legislation and policies for planning, development, conservation, protection of shared watercourses, and allocation of the resources thereof; and
- (e) Promote research and technology development, information exchange, capacity building, and the application of appropriate technologies in shared watercourses management (*Ibid*).

3.3.5 ZACPLAN Projects

In 1987, the then Southern African Development Coordination Conference (SADCC), now the Southern African Development Community (SADC), adopted the Zambezi River Action Plan (ZACPLAN) as part of economic integration, cooperation and development of southern African countries. The objective of ZACPLAN is to achieve environmentally sound planning and management of water and related resources in the Zambezi river basin. Through the ZACPLAN, a number of projects have been undertaken (Euroconsult Mott MacDonald, 2007).

A major achievement was the signing of the Agreement on the establishment of the Zambezi Watercourse Commission (ZAMCOM). The ZAMCOM Agreement was signed by seven of the eight riparian countries on 13th July 2004. Its aim is to promote equitable and reasonable use of the water resources of the Zambezi River

Basin and is also expected to promote efficient management and sustainable development among the riparian states of Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe (Euroconsult Mott MacDonald, 2008).

The SADC Water Division (SADC-WD) within the framework of ZACPLAN and through an instruction of the former SADC Committee of Ministers of Water (Zanzibar, June 1999) facilitated the ZAMCOM negotiation process. A core project under ZACPLAN is the Zambezi Action Plan Project 6 (ZACPRO 6) titled “Development of an Integrated Water Management Plan for the Zambezi River Basin” which was implemented in two phases. Phase 1 (ZACPRO 6.1), implemented between 1995 and 1999, was concerned with the development of a sectoral knowledge base of water and related information to provide a sound basis for the planning and development of the water resources of the Zambezi Basin (*Ibid*).

The overall objective of ZACPRO 6 Phase 2 was to improve integrated water resources management to facilitate social and economic development and protection against floods, droughts, water resources pollution and environmental degradation in the Zambezi River Basin. The immediate objective of the project is to assist and facilitate the efforts of the Zambezi riparian states to create and develop an enabling institutional environment for the achievement of the overall objective. It is recognized that the formation of ZAMCOM will be critical in the implementation of the Integrated Water Resources Management (IWRM) Strategy for the Basin (*Ibid*).

3.4 Present Utilisation

The current major uses of the Zambezi water are:

- Abstractions for primary purposes ranging from individual domestic to local authority and urban level
- Abstractions for mining purposes
- Abstractions for industrial use
- Abstractions for agricultural purposes
- Tourism/recreation and navigational use
- Energy generation requirements
- Environmental usage

Of these uses, the current study focuses on extractive usage of water from the Zambezi River / Lake Kariba between Kazungula and Kariba Dam.

CHAPTER 4: METHODOLOGY, ANALYSIS AND DISCUSSION

4.1 Methodology

The study involved the collection of both primary and secondary data from the study area. Primary data was collected through physical contacts with the target water users through aural interviews as well as pump specifications where applicable. Where it was not possible to estimate usage from any of the above methods, estimations were made based on populations served or the crops and hectareage irrigated. While some of these uses are based on stipulated allocations established through the involvement of the permit-issuing institutions (Water Board – Zambia and ZINWA – Zimbabwe), a significant number of users are not on record in the appropriate registers.

Secondary data was derived from the Zambezi River Authority databases. These data included the following:

- Inflows from the mainstream Zambezi River as measured at Victoria Falls;
- Local flows from the Lower Catchment tributaries;
- Net evaporation for Lake Kariba;
- Reservoir characteristics (elevation, storage, surface area and outlet capacity curves);
- Reservoir operation criteria (Flood Control Rule Curve);
- Hydrologic balance; and
- Power plant characteristics.

The data were then integrated into an input file for the HEC-3 computer programme for purposes of running simulations of a reservoir operation system.

HEC stands for ‘Hydrologic Engineering Centre’ of the US Army Corps of Engineers (USACE). The original version of the computer programme was developed in 1965, releasing the HEC-3 Reservoir System Analysis for Conservation version in 1974. The programme simulates the operation of a reservoir system for such conservation purpose as water supply, irrigation, navigation, recreation, low-flow augmentation and hydroelectric power. The present version used in this study was adapted and

prepared by SNC-Shawinigan using the Microsoft FORTRAN compiler version 5.1 (Shawinigan Engineering, 1995).

In running the HEC-3 programme, the following assumptions were made:

- That water abstraction remains constant over the simulation period, with no (zero) return flow;
- That the inflows into the Lake constitutes the Zambezi River long-term monthly mean flows (1908/9 – 2008/9) as measured at Victoria Falls hydrometric station;
- Lower Catchment tributary inflows estimated from the Victoria Falls flows using factors derived from ungauged Lower Catchment rainfall-runoff modeling and water balance computations for Lake Kariba;
- Net Evaporation estimated from Long-term lake-side measurements ;
- Installed power capacity at Kariba (combined) stands at 1,470 MW, an increase from the 1,266 MW capacity following the recent uprating programmes on both the South and North-Bank Plants. Projected capacity is 1,830 MW, when including the peaking power capacity of 360 MW being developed on the North Bank (Extension) Project; and
- Overall power plant efficiency remains constant at 86%.

Table 2 below shows the input data used in the simulation.

Table 2: Hydrological Data used in the Kariba Dam Multi-purpose Simulations

	Month											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Long-term Victoria Falls Mean Flows (m³/s)	261	264	395	642	1055	1919	2716	2345	1473	768	467	337
Lower Catchment inflows (m³/s)¹	7	39	358	609	916	534	185	63	40	25	18	12
Mean Net Evaporation	168	180	(29)	(75)	5	157	146	123	135	195	114	149
Flood Control Rule Curve (m.a.s.l)	488.50	487.00	485.50	484.80	484.15	485.95	487.75	488.50	488.50	489.50	488.50	488.50

¹ As computed from Victoria Falls flows using factors derived from long-term water balance computations

4.2 Data Analysis and Results

Results of the water usage surveys are presented as Appendices 1 and 2, representing total extractive usage of the Zambezi River / Lake Kariba water between Kazungula and Kariba Dam in Zambia and Zimbabwe, respectively.

4.2.1 Water Use Demands

The data shows that an estimated total of $165,167 \text{ m}^3\text{day}^{-1}$ is abstracted on the Zambian side, while approximately $2,374,885 \text{ m}^3\text{day}^{-1}$ is abstracted on the Zimbabwean side, bringing the total to $2,540,052 \text{ m}^3\text{day}^{-1}$.

Of the total abstraction from the Zambezi River / Lake Kariba on the Zambian side, $52,640 \text{ m}^3\text{day}^{-1}$ of water is abstracted for primary use (domestic / municipal supply) while $106,527 \text{ m}^3\text{day}^{-1}$ is abstracted for agricultural use (irrigation and crocodile rearing). These figures are graphically presented in Figure 2 below.

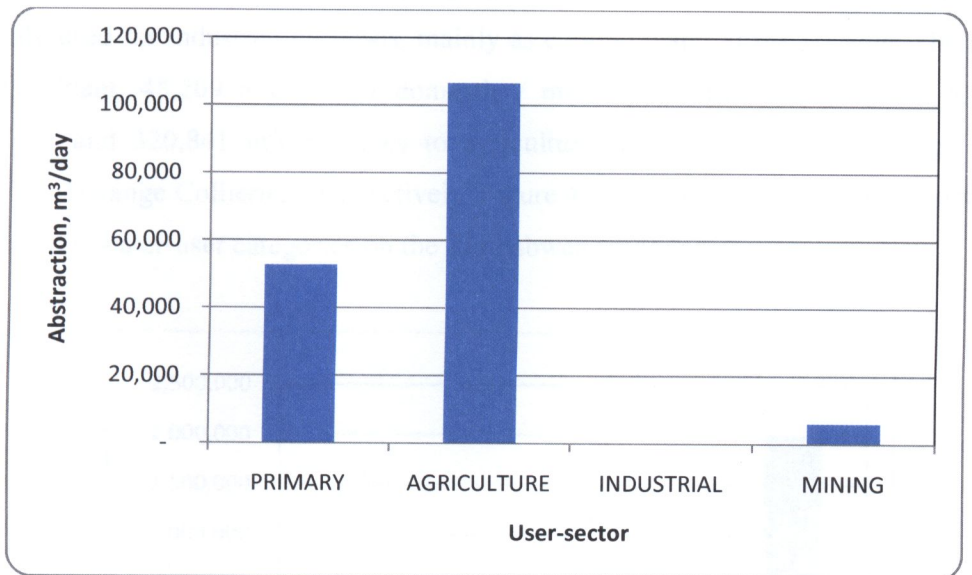


Figure 2: Estimated Volumes of Abstraction by Sector on the Zambian Side between Kazungula and Kariba Dam – as in 2009.

The water use proportions presented in the above figure are further summarized in Figure 3 below, showing that agriculture is the largest user on the Zambian side at 64% and mining at 4%, while industrial usage is inexistent.

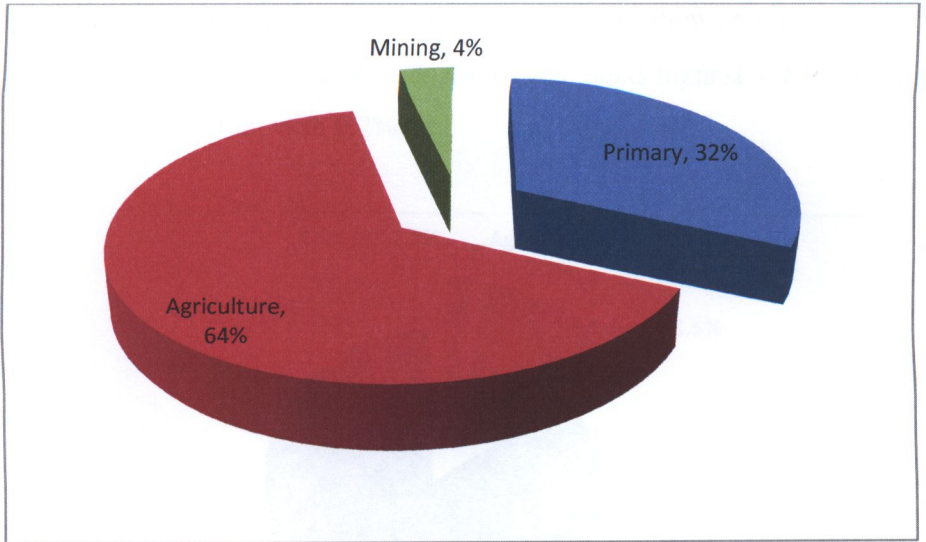


Figure 3. Proportions of Abstractions by Sector on the Zambian Side between Kazungula and Kariba Dam – as in 2009.

On the Zimbabwean side, approximately $2,000,000 \text{ m}^3 \text{ day}^{-1}$ of the water abstracted is mainly used for industrial purposes, mainly as cooling water at the Hwange Thermal Power Plant, $48,209 \text{ m}^3 \text{ day}^{-1}$ for domestic / municipal water supply, while $5,835 \text{ m}^3 \text{ day}^{-1}$ and $320,841 \text{ m}^3 \text{ day}^{-1}$ goes to agriculture (mostly crocodile farming) and mining (Hwange Collieries), respectively. Figure 4 below is a graphical representation of the four water-user categories on the Zimbabwean side.

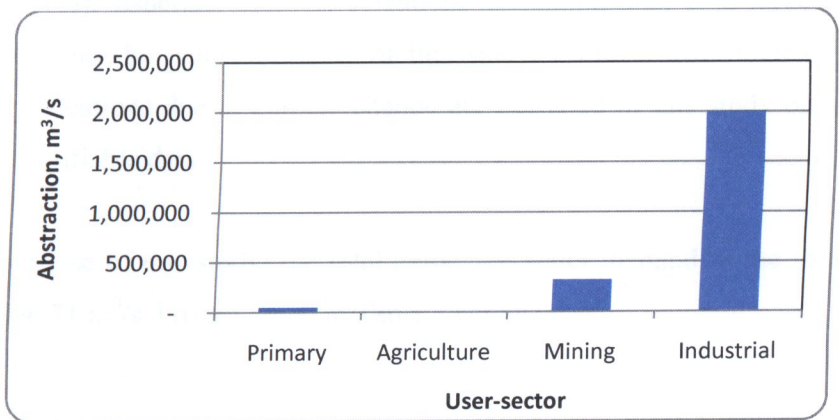


Figure 4. Estimated Volumes of Abstraction by Sector on the Zimbabwean Side between Kazungula and Kariba Dam – as in 2009.

Figure 5 below shows the same data presented in Figure 4 above but as proportions of the total water usage on the Zimbabwean side. The figure shows a stark contrast with the situation on the Zambian side as industrial usage ranks highest at 84.2%, while agriculture is at the bottom with 0.2%.

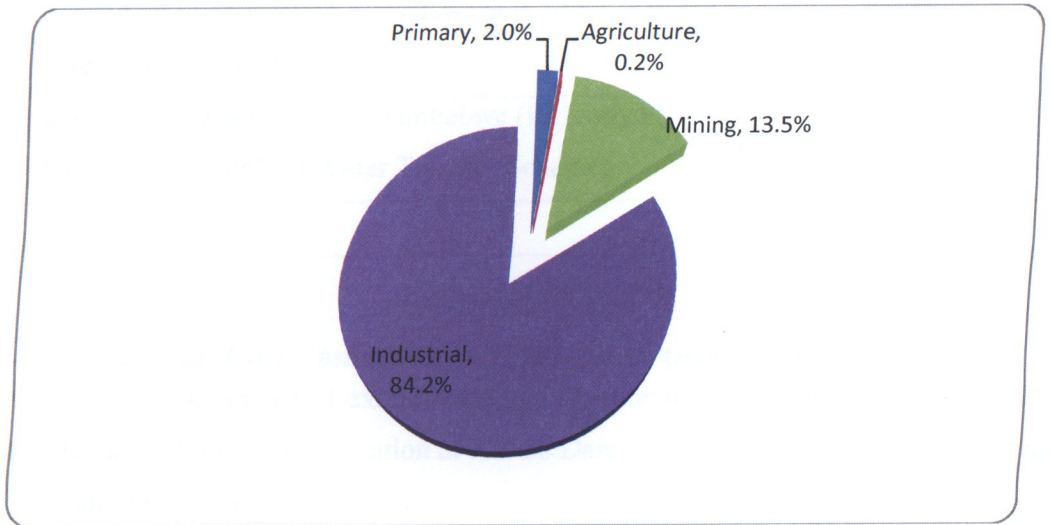


Figure 5. Proportions of Abstractions by Sector on the Zimbabwean Side between Kazungula and Kariba Dam – as in 2009.

Non-consumptive users of the Zambezi waters, including hydro-power at Victoria Falls (Zambia), fisheries, tourism/recreation, navigation and, to a large extent, the environment are by nature not part of this study. Further, hydrological and water usage modifications due to climate change are excluded in this study on account of lack of quantifiable data.

For the purpose of this study, the total extractive water demand in the study area is estimated at 71 m³/s, broken down in Table 3 below.

Table 3: Current and Projected Extractive Water Demand used in the Study

Usage Description	Demand (m³/s)
Current abstraction	29
Projected irrigation demand around Lake Kariba	10
Planned large abstraction by Botswana (Chobe/Zambezi Water Transfer Scheme)	16
Planned large abstraction by Zimbabwe (Bulawayo-Matabeleland-Zambezi Water Transfer Scheme)	16
Total (2025)	71

4.2.2 Impact of Water Abstraction on Hydro-power Generation

In assessing the impact of extractive usage of water from the Zambezi River / Lake Kariba on hydro-power generation at Kariba Dam, computer simulations were carried out under the following scenarios:

Scenario 1: Initial lake level at Low Supply Level (475.5m) and Current Total generation capacity (1,470 MW)

Scenario 2: Initial lake level at Median level (482.0m) and Current Total generation capacity (1,470 MW)

Scenario 3: Near-Full Supply Level (487.5m) and Projected Capacity (1,830 MW)

Each of the three Scenarios was run separately but under a common hydrological regime as presented in Table 3 above. The results of these simulations are presented in Tables 4, 5 and 6 below.

The results of Scenario 1 (Table 4) show total failures (shaded tale cells) to meet both the required energy and abstraction demands in the first two months and only energy to varying degrees in the third, fourth and last three months of the simulation period.

Table 4: Scenario 1 – Initial lake level at Low Supply Level (475.5m) and Current Total Generation Capacity (1,470 MW), Lake Kariba

	Month											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Required Generation (MW)	1470	1470	1470	1470	1470	1470	1470	1470	1470	1470	1470	1470
Simulated Generation (MW)	0	0	571	984	1390	1470	1470	1470	1470	383	189	23
Abstraction Demand (m³/s)	71	71	71	71	71	71	71	71	71	71	71	71
Simulated Allocated (m³/s)	0	0	71	71	71	71	71	71	71	71	71	71
Reservoir Flood Control Rule Curve (m.a.s.l)	488.50	487.00	485.50	484.80	484.15	485.95	487.75	488.50	488.50	489.50	488.50	488.50
Simulated End-of-Month Lake Level (m)	475.10	475.29	475.50	475.50	475.50	475.57	475.92	476.00	475.54	475.50	475.50	475.50
Spillage (m³/s)	0	0	0	0	0	0	0	0	0	0	0	0

The shaded cells in the above table indicate that as the Lake is building up from the barest minimum storage level of 475.5m (i.e., theoretically ‘empty’) at the beginning of the simulation season, both the energy and abstraction requirements are impossible to meet due to evaporation. In other words, practically all the inflow ends up evaporating from the Lake and hence the simulated drawing down of the reservoir to below Low Supply Level. On the other hand, insufficient inflows from July to September barely maintain the reservoir levels at the Lowest Supply Level (475.5m) but somehow manage to allocate the full abstraction requirement. This is so because whereas energy generation requires some reasonable head, abstraction does not necessarily require it.

The situation becomes clearer with the second Scenario where the reservoir storage is fairly high at the beginning of the simulation season. The results of Scenario 2 are given in Table 5 below.

Table 5: Scenario 2 – Initial lake level at Median level (482.0m) and Current Total Generation Capacity (1,470 MW), Lake Kariba

	Month											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Required Generation (MW)	1470	1470	1470	1470	1470	1470	1470	1470	1470	1470	1470	1470
Simulated Generation (MW)	1470	1470	1470	1470	1470	1470	1470	1470	1470	1470	1470	1470
Abstraction Demand (m³/s)	71	71	71	71	71	71	71	71	71	71	71	71
Simulated Allocation (m³/s)	71	71	71	71	71	71	71	71	71	71	71	71
Res. Flood Control Rule Curve (m.a.s.l)	488.50	487.00	485.50	484.80	484.15	485.95	487.75	488.50	488.50	489.50	488.50	488.50
Simulated End-of-Month Lake Level (m)	480.92	479.85	479.18	478.83	478.81	478.92	479.27	479.39	478.99	478.09	477.08	475.93
Spillage (m³/s)	0	0	0	0	0	0	0	0	0	0	0	0

However, Scenario 3 (Table 6) shows some failure to meet the energy requirement as can be seen in the shaded cells of the table (July – September). This happens because of the elevated generation requirement which tends to overdraw the reservoir storage as the reservoir release outstrips firm (mean) inflow.

Table 6: Scenario 3 – Near-Full Supply Level (487.5m) and Projected Generation Capacity (1,830 MW), Lake Kariba

	Month											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Required Generation (MW)	1830	1830	1830	1830	1830	1830	1830	1830	1830	1830	1830	1830
Simulated Generation (MW)	1830	1830	1830	1830	1830	1830	1830	1830	1830	1187	189	23
Abstraction Demand (m³/s)	71	71	71	71	71	71	71	71	71	71	71	71
Simulated Allocation (m³/s)	71	71	71	71	71	71	71	71	71	71	71	71
Res. Flood Control Rule Curve (m.a.s.l)	488.50	487.00	485.50	484.80	484.15	485.95	487.75	488.50	488.50	489.50	488.50	488.50
Simulated End-of-Month Lake Level (m)	480.65	479.30	478.32	477.65	477.34	477.13	477.18	476.97	476.22	475.50	475.50	475.50
Spillage (m³/s)	0	0	0	0	0	0	0	0	0	0	0	0

4.2.3 Water Balance Model vis-à-vis Energy Generation

The simulation tables given above (Tables 4, 5 and 6) depict water balance scenarios for the different energy versus abstraction requirements. From these tables, the following deductions can be drawn:

- i. Failures and shortages were declared in the first Scenario on account of the following factors:
 - a. Both energy and abstraction requirements could not be met in the first two months on account of inflows that were too low to offset evaporation from the Lake – a situation that resulted in drawing down the reservoir to below the Minimum Supply Level;
 - b. Energy requirements in the low-inflow months October – February and July – September could not be met due to grossly reduced head that required elevated reservoir releases. Thus, the system allocated the full abstraction demand, presumably due to the fact that retaining this amount of water would still have had an insignificant effect on the energy demand.
- ii. The second Scenario had no shortages in terms of either energy or abstraction requirements.
- iii. Energy shortages were declared under Scenario 3 (Near-full supply level and increased target generation) for the months July – September, probably due to increased energy requirement that assumed constant peak-power demand. However, water abstraction requirements were met throughout the period, probably due to the same reason given in item i)b above.

4.2.4 Water Allocation Policy for Non-Hydro-power Users

The study has shown that whereas Lake Kariba was originally created for the sole purpose of building head for hydro-power generation, several non-hydro-power sectors have benefitted. It is evident that although the reservoir flood control rule curve requires that the Lake Level should be in the order of 488.5 m.a.s.l at the end of October (Table 2), non-hydro-power usage to the tune of 71 m³/s under normal (average) hydrological conditions (Table 4) does not have any impact on hydro-power

generation at Kariba Dam. Based on the three reservoir scenarios in this study, and notwithstanding the reservoir flood control rule curve, the Scenario 2 seems to depict that non-hydro-power extractive usage of Lake Kariba waters is tolerable under normal hydrological and energy generation (that is, excluding peaking power capacity) conditions as long as the Lake Level at the beginning of the hydrological season (October) is around 482.00 m.a.s.l.

4.3 Discussion

This study reveals a stark contrast in water usage patterns between Zambezi River and Lake Kariba riparian zones in Zambia and Zimbabwe. This situation may be attributed to the fact that whereas most of the Zimbabwean stretch constitutes wildlife protected area, the case is not different on the Zambian side. Thus, irrigation for agriculture – and hence more water usage – on the latter is more developed than on the former. The largest abstractor for irrigation on the Zambian side is Zambezi Farm (abstracting $2,000 \text{ m}^3\text{day}^{-1}$ mostly for fodder cropping at its Sinazongwe Farm (formally Northern Grain Growers Ltd)). Conversely, however, industrial water usage is much higher on the Zimbabwean side, largely on account of the vast quantities of water required as cooling water at the huge thermal power plant in Hwange, a situation that is practically absent on the Zambian side. As a matter of fact, the whole study area is practically devoid of any other industrial activity of any significance.

Coincidentally, primary water demand seems balanced between the two riparian sides with about $52,000 \text{ m}^3\text{day}^{-1}$ and $48,000 \text{ m}^3\text{day}^{-1}$ apiece, probably due to similar levels of urbanization on either side of this Zambezi River stretch.

On the other hand, mining on the Zimbabwe side takes far much more water compared to that on the Zambian side. Again, this can be attributed to the difference in the magnitude of the coal mining – the only major investment in this sector in the region – between the two sides.

That be as it may, it is clear that the combined water abstraction on the study area seems to have an insignificant impact on hydropower generation at Kariba Dam, both at the moment and in the near future (2025). The results of this study show that the only failure that may be attributed to water abstraction could be under Scenario

However, it is also evident that even without the water withdrawal to the level of m^3/s , the energy shortage would still occur under the circumstances owing to the low initial storage (practically empty) coupled with not only the rather low inflow but more so because of the high evaporation. This reality is manifest in the second scenario where no shortages whatsoever were declared.

The third Scenario shows only energy shortages, indicating that the target generation was way too high for the twelve months. This was clearly expected considering that the additional 360 MW required from the North Bank Power Plant would only be invoked at peak demand times only. It is quite evident from the above results that any scenario with initial storage higher than Scenario 2 but for the same energy requirement as in the latter case would still result in no failures or shortages.

Overall, the abstraction level used in this study assumes continuous extraction at the level throughout the year, and yet the reality is that irrigation demand drastically falls during the rainy season – a situation that shows that the actual total extractive usage would be well below this level. This situation further lends weight to the observed low impact of extractive water usage on hydropower generation at Kariba Dam.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The study confirms earlier studies that water demand from the Zambezi River and Lake Kariba for uses other than hydropower is less than 1% of the Kariba Reservoir Live Storage. It has also shown that industry (thermal energy generation, Zimbabwe) is the largest consumer of water at the moment, followed by agriculture (irrigation, Zambia).

The study also shows that water abstraction from the Zambezi River and Lake Kariba at current and projected levels is too insignificant to have a noticeable impact on hydropower generation. However, the study has also shown that priority for hydro-power generation at Kariba Dam may only be a factor in cases where 1) hydrological conditions are below average, and coupled with 2) the Lake level being lower than 482.00 m.a.s.l in October. It is also clear that the present reservoir operation regime – though heavily tilted towards single-purpose utilization – does not in any way impinge on other non-hydro-power needs.

5.2 Recommendations

Lake Kariba therefore offers attractive opportunities for the two countries to utilize its waters and contribute to wealth creation and poverty reduction for their nationals in general, and the local riparian communities in particular. It is therefore recommended as follows:

- i) Agricultural production, taking advantage of the waters of the Zambezi / Lake Kariba, should be intensified among riparian and peripheral communities in order to create wealth and reduce poverty and hunger
- ii) Further studies need to be undertaken in the areas of trans-boundary non-hydro-power water sharing arrangements

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APPENDICES

Appendix 1: List of Water Abstractors from the Zambezi River and Lake Kariba between Kazungula and Kariba Dam – Zambian Side

Water User Name	Location	Area/Village	Water Resource	Quantity of Water (m3/day)	Area Irrigated (ha)	User Category	Southing	Eastings
Buleyamalima Cooperative	Sinazongwe	Buleyamalima	Lake Kariba	-	73.6	Irrigation	17.1245	27.54056
Blue Water Fisheries	Sinazongwe	Buleyamalima	Lake Kariba	N/A	0	Crocodile Farming	17.131222	27.54536
Crochide	Sinazongwe	Sinazongwe	Lake Kariba	21	0	Domestic/ Crocodile Farming	17.164611	27.531078
Zambeef	Sinazongwe	Sinazongwe	Lake Kariba	86,400	2000	Irrigation	17.22533	27.463139
Lwiimbo Lwa Zambezi Safaris Limited	Sinazongwe	Siansowa	Lake Kariba	10	0	Domestic	17.45036	27.38158
Maaze Holdings	Sinazongwe	Siansowa	Lake Kariba	80	0	Domestic	17.45069	27.38681
Zongwe Farming Enterprises	Sinazongwe	Siansowa	Lake Kariba	3,500	0	Crocodile Farming	17.45303	27.38158
Siatwiinda Irrigation Scheme	Sinazongwe	Siatwiinda	Lake Kariba	-	69	Irrigation	17.43933	27.31672
Luchinze Crocodiles	Maamba	Lunchinze	Lake Kariba	200	0	Crocodile Farming	17.34756	27.400972
Lakar Fishing Limited	Maamba	Sialwala	Lake Kariba	1	0	Kapenta Fisheries	17.28597	27.41256
Maamba Collieries	Maamba	Sialwala	Lake Kariba	6,000	0	Domestic/ Mining	17.28564	27.411667
Adria F. C	Chipepo	Chipepo	Lake Kariba	0	0	Domestic	16.79458	27.88252
Chipepo High School	Chipepo	Chipepo	Lake Kariba	721	0	Domestic	16.80136	27.872417
Southern Water & Sewerage- L/Stone	Livingstone	Livingstone	Zambezi River	50,000	0	Domestic	17.88519	25.840139
Sun International (Z) Ltd	Livingstone	Livingstone	Zambezi River		0	Domestic	17.913294	25.86153
Zesco (Victoria Falls Power Station)	Livingstone	Livingstone	Zambezi River	610	0	Domestic/ Power generation	17.932941	25.86153

Water User Name	Location	Area/Village	Water Resource	Quantity of Water (m3/day)	Area Irrigated (ha)	User Category	Southing	Easting
SWASCO (Kazungula)	Kazungula	Kazungula	Zambezi River	150	0	Domestic	17.78922	25.26683
Mambova Investments	Kazungula	Mambova	Zambezi River	4	0	Domestic	17.74886	25.18844
Mililo Mr	Kazungula	Kazungula	Zambezi River	1	0.5	Irrigation	17.79486	25.27375
Next Trading Pty Ltd	Kazungula	Kazungula	Zambezi River	1	0	Domestic	17.79817	25.28031
Katombora Reformatory School	Kazungula	Kazungula Road	Zambezi River	174	1.25	Domestic/ Irrigation	17.83594	25.40583
Royal Chuundu	Kazungula	Kazungula Road	Zambezi River	5	0	Domestic	17.84319	25.41756
Mystique Investments	Kazungula	Kazungula Road	Zambezi River	3	0	Domestic	17.83969	25.45367
Islands of Siankaba	Kazungula	Kazungula Road	Zambezi River		0	Domestic	17.83347	25.57367
Cool Amarula	Kazungula	Kazungula Road	Zambezi River	12,600	440	Irrigation	17.785	25.57367
Kubu Zambezi	Livingstone	Kazungula Road	Zambezi River	4	0	Domestic	17.83025	25.64756
Water Berry Lodge	Livingstone	Kazungula Road	Zambezi River	120	0	Domestic/ Fish Farming	17.83281	25.63547
L/stone Tobacco Farm	Livingstone	Kazungula Road	Zambezi River		60	Irrigation	17.81756	25.62806
Zambezi Farm (Nkwazi Golfing & Housing Estates)	Livingstone	Kazungula Road	Zambezi River	2	0	Domestic	17.82589	25.62725
Amoret Farm	Livingstone	Kazungula Road	Zambezi River			No Activity	17.82975	25.63678
Kayube Estate	Livingstone	Kazungula Road	Zambezi River	500	10	Domestic/ Irrigation	17.82056	25.65719
Nzou Farming Ltd	Livingstone	Kazungula Road	Zambezi River	2,250	45	Irrigation	17.7975	25.67692
Chuundu farm	Livingstone	Kazungula Road	Zambezi River	500	10	Domestic/ Irrigation	17.80417	25.67667

Water User Name	Location	Area/Village	Water Resource	Quantity of Water (m3/day)	Area Irrigated (ha)	User Category	Southing	Easting
Chundukwa Adventures	Livingstone	Kazugula Road	Zambezi River		0	Domestic/ Irrigation	17.80917	25.67231
Natural Mystic	Livingstone	Kazugula Road	Zambezi River	2	0	Domestic/ Irrigation	17.80619	25.68906
Tongabezi Lodge	Livingstone	Kazugula Road	Zambezi River		0	Domestic/ Irrigation	17.81975	25.70753
River Club	Livingstone	Kazugula Road	Zambezi River	30	0	Domestic/ Irrigation	17.8215	25.70544
Zambezi Nkuku	Livingstone	Kazugula Road	Zambezi River	20	0	Poultry Farming	17.83597	25.71858
Bindi Meadow Farms	Livingstone	Kazugula Road	Zambezi River	1	300	Irrigation	17.82792	25.70394
No Name farm	Livingstone	Kazugula Road	Zambezi River		0	Domestic	17.82375	25.73614
Dicks Land Farm	Livingstone	Kazugula Road	Zambezi River	1	0	Domestic	17.83452	25.73303
Masilelo Farm	Livingstone	Kazugula Road	Zambezi River		0	Domestic	17.83633	25.737347
Thorn Tree	Livingstone	Kazugula Road	Zambezi River		0	Domestic	17.84331	25.75542
Zambezi Elephant Trails	Livingstone	Kazugula Road	Zambezi River		0	Domestic	17.83931	25.75567
Sussie & Chuma	Livingstone	Kazugula Road	Zambezi River		0	Domestic	17.84111	25.77133
Elephant Trails	Livingstone	Livingstone	Zambezi River		0	Domestic		
Mubuyu Christian Academy	Siavonga	Matinangala	Lake Kariba	14	0	Domestic	16.47583	28.66253
Fisherman's Cove Lodge	Siavonga	Matinangala	Lake Kariba	4	0	Domestic	16.48369	28.660111
Sandy Beach	Siavonga	Matinangala	Lake Kariba	2	0	Domestic	16.48561	28.66508
Brayshaw Mr (Baobab Bay)	Siavonga	Matinangala	Lake Kariba	2	0	Domestic	16.47875	28.67347
Island Fishing Industries	Siavonga	Matinangala	Lake Kariba	3	0	Domestic	16.50961	28.70278

Water User Name	Location	Area/Village	Water Resource	Quantity of Water (m3/day)	Area Irrigated (ha)	User Category	Southing	Easting
Siavonga Kapenta Industries	Siavonga	Matinangala	Lake Kariba	3	0	Domestic	16.51094	28.70308
Deep Six	Siavonga	Matinangala	Lake Kariba		0	Domestic	16.51289	28.701
Kaliolio Crocodile Farm	Siavonga	Matinangala	Lake Kariba	200	0	Crocodile Farm	16.52069	28.70342
Animal Proteins	Siavonga	Kanyejele	Lake Kariba	40	0	Domestic	16.52772	28.69347
MacWil	Siavonga	Kanyejele	Lake Kariba	4	0	Domestic	16.52306	28.70322
Kariba Enterprises	Siavonga	Kanyejele	Lake Kariba		0	Domestic	16.52286	28.70222
Sumbu Crocodile Ltd	Siavonga	Kanyejele	Lake Kariba	400	0	Crocodile Farm	16.53261	28.68486
A.M Motors	Siavonga	Kanyejele	Lake Kariba	2	0	Domestic	16.53658	28.68214
Nyaminyami Adventures Trust	Siavonga	Kanyejele	Lake Kariba	2	0	Domestic	16.537	28.68203
Tune Enterprises	Siavonga	Kanyejele	Lake Kariba	16	0	Domestic	16.53722	28.68408
Lake Harvesters Ltd	Siavonga	Kanyejele	Lake Kariba	7	0	Domestic	16.53125	28.68669
King Kapenta	Siavonga	Kanyejele	Lake Kariba	15	0	Domestic	16.53172	28.68803
Harvest Help	Siavonga	Kanyejele	Lake Kariba	2	0	Domestic	16.52661	28.68989
New Hotel Under Construction	Siavonga	Kanyejele	Lake Kariba		0	Domestic	16.54178	28.68894
Gary Wade Mr.	Siavonga	Kanyejele	Lake Kariba	5	0	Domestic	16.53975	28.68972
Lake Kariba Inns	Siavonga	Siavonga	Lake Kariba	150	0	Domestic	16.53642	28.70444
Lake Safari Lodge	Siavonga	Siavonga	Lake Kariba	40	0	Domestic	16.54211	28.70828
Southern Water and Sewerage Co.- Siavonga	Siavonga	Siavonga	Lake Kariba	135	0	Water Supply	16.53506	28.71358
Transcontinental (Z) Pty Ltd	Siavonga	Siavonga	Lake Kariba	30	0	Domestic	16.05402	28.70792
Manchinchi Bay Lodge	Siavonga	Siavonga	Lake Kariba	30	0	Domestic	16.53744	28.72506
Eagles Rest	Siavonga	Siavonga	Lake Kariba	18	0	Domestic	16.53653	28.72897
Zefa Lodge	Siavonga	Siavonga	Lake Kariba	10	0	Domestic	16.53486	28.72647
Piete Lieberbugy	Siavonga	Siavonga	Lake Kariba	3	0	Domestic	16.53492	28.7245

Water User Name	Location	Area/Village	Water Resource	Quantity of Water (m3/day)	Area Irrigated (ha)	User Category	Southing	Eastings
Country Mr	Siavonga	Siavonga	Lake Kariba	3	0	Domestic	16.53494	28.72447
O'Donnel Mr	Siavonga	Siavonga	Lake Kariba	4	0	Domestic	16.53478	28.72458
Nadal George (E.M.L)	Siavonga	Siavonga	Lake Kariba	1	0	Domestic	16.53472	28
Agent Mr	Siavonga	Siavonga	Lake Kariba	2	0	Domestic	16	28
Harrison A.W	Siavonga	Siavonga	Lake Kariba	3	0	Domestic	16	28
Puffet Mrs	Siavonga	Siavonga	Lake Kariba	2	0	Domestic	16	28
Limbada Mr	Siavonga	Siavonga	Lake Kariba	5	0	Domestic	16	28
Wahlg John (Mr)	Siavonga	Siavonga	Lake Kariba	4	0	Domestic	16	28
Moonga Petrol	Siavonga	Munyama	Lake Kariba	1	0	Domestic	16.53044	28.44697
Harvest Help (Munyama)	Siavonga	Munyama	Lake Kariba	10	0	Domestic	16.53356	28.44617
Musika Farm	Siavonga	Munyama	Lake Kariba	3	1	Irrigation	16.53367	28.44792
Kasenzi Mr	Siavonga	Munyama	Lake Kariba	5	1	Irrigation	16.53392	28.44923
Chiboola Lodge	Siavonga	Manchisi	Lake Kariba	4	0	Domestic	16.50861	28.51678
Robby Mr	Siavonga	Manchisi	Lake Kariba		0	Domestic	16.50972	28.51806
Lotri Bay Lodge (Dubler Mr)	Siavonga	Manchisi	Lake Kariba	5	0	Domestic	16.50475	28.53447
Mine Under Development (Munyama)	Siavonga	Munyama	Lake Kariba			Mining	16.46653	28.52164
Butete Bay Lodge	Siavonga	Butete	Lake Kariba	8	0	Domestic	16.50011	28.58492
Hambayi Mr (Pa Scale)	Siavonga	Gwena	Lake Kariba		0	Domestic	16.49969	28.609
Dedrick Chris (Kalembula)	Siavonga	Gwena	Lake Kariba	2	0	Domestic	16.49781	28.61881
Grill Joseph	Siavonga	Gwena	Lake Kariba		0	Domestic	16.49833	28.61667
Hapunda Mr	Siavonga	Gwena	Lake Kariba		0	Domestic	16.49944	28.61694
Mackintosh Mr	Siavonga	Gwena	Lake Kariba		0	Domestic	16.49889	28.62222
Fish Eagle	Siavonga	Matinangala	Lake Kariba	5	0	Domestic	16.51708	28.70706
Casilli Gillan	Siavonga	Siavonga	Lake Kariba	5	0	Domestic	16.53558	28.71906
Leisure Bay	Siavonga	Siavonga	Lake Kariba	40	0	Domestic	16.53939	28.71922

Water User Name	Location	Area/Village	Water Resource	Quantity of Water (m3/day)	Area Irrigated (ha)	User Category	Southing	Easting
Sobeki Canoe Enterprises	Siavonga	Namomba	Zambezi River	2	0	Domestic	16.36894	28.84592
New Lodge Under Construction	Siavonga	Namomba	Zambezi River	2	0	Domestic	16.35964	28.8395
Masau Camp	Siavonga	Namomba	Zambezi River	2	0	Domestic	16.35681	28.83761
Musokwe Camp	Siavonga	Namomba	Zambezi River	1	0	Domestic	16.35589	28.83689
Prise Joshua	Siavonga	Mulopa	Zambezi River	1	0	Domestic	16.32883	28.82664
			TOTAL	165,167	Cubic meters per day			

Appendix 2: List of Water Abstractors from the Zambezi River and Lake Kariba between Kazungula and Kariba Dam – Zimbabwean Side

Water User Name	Location	Source	m ³ /day	Category	Southing	Eastings	X	Y
ZINWA	Victoria Falls	Zambezi River	17,496	Industrial	17.8259	25.30162	319990	8028210
ZINWA	Kazungula	Zambezi River	1,513	Industrial	17.85506	25.38541	328916	8025111
Safari Lodge	Victoria Falls	Zambezi River	600	Domestic	17.91733	25.81922	374944	8018545
Elephant Hills	Victoria Falls	Zambezi River	50	Irrigation	17.91023	25.83028	376151	8019363
Spencer's Creek	Victoria Falls	Zambezi River	710	Domestic	17.90116	25.82055	375036	8020366
A' Zambezi Hotel	Victoria Falls	Zambezi River	50	Domestic	17.90117	25.8217	375183	8020302
Imbabala Lodge	Kazungula	Zambezi River	1	Domestic	17.81838	25.28448	318176	8029086
Kazungula W.L Safari	Kazungula	Zambezi River	1	Domestic	17.84243	25.32797	322816	8026456
ZINWA	Katombora	Zambezi River	400	Industrial	17.85506	25.38541	328916	8025111
Matetsi Game Reserve	Katombora	Zambezi River	5	Environ	17.86957	25.50198	341285	8023606
Hwange Coilliery Co.	Hwange	Zambezi River	320,841	Industrial	18.08001	26.69286	467495	8000941
ZESA (Hwange)	Hwange	Zambezi River	2,000,000	Industrial	18.074	26.67306	465358	8001588
Sundowner	Hwange	Zambezi River	3	Domestic	18.07617	26.69948	468202	8001361
Olive Beadle Fishing	Hwange	Zambezi River	205	Domestic	18.02854	26.79477	478274	8006647
Msuma Fishing Resort	Hwange	Zambezi River	40	Domestic	18.01855	26.82633	481616	8007758
Breamland Lodge	Hwange	Zambezi River	1	Domestic	18.02545	26.80262	479113	8006981

Water User Name	Location	Source	m3/day	Category	Southing	Easting	X	Y
Mlibizi Hotel	Mlibizi	Lake Kariba	650	Domestic	17.93902	27.07431	507875	8016560
Mlibizi Zambezi Resort	Mlibizi	Lake Kariba	650	Domestic	17.94334	27.07281	507706	8016084
Mubuyu Lodge	Mlibizi	Lake Kariba	40	Domestic	17.93469	27.0752	507967	8017039
Stand 65	Mlibizi	Lake Kariba	5	Domestic	17.93511	27.07442	507881	8016995
Happy Days Stand 64	Mlibizi	Lake Kariba	5	Domestic	17.93492	27.07386	507822	8017018
Stand 63	Mlibizi	Lake Kariba	5	Domestic	17.93484	27.07413	507853	8017023
Stand 171	Binga	Lake Kariba	2	Domestic	17.58506	27.3584	538043	8055688
Stand 172	Binga	Lake Kariba	2	Domestic	17.58513	27.35847	538037	8055678
Stand 177	Binga	Lake Kariba	2	Domestic	17.58665	27.36074	538273	8055511
Stand 180	Binga	Lake Kariba	5	Domestic	15.58849	27.36171	538376	8055306
Stand 174	Binga	Lake Kariba	2	Domestic	17.58497	27.35931	538177	8055675
Stand 175	Binga	Lake Kariba	5	Domestic	17.58605	27.35992	538186	8055579
Stand 176	Binga	Lake Kariba	5	Domestic	17.58608	27.36062	538272	8055570
Stand 178	Binga	Lake Kariba	5	Domestic	17.58724	27.36094	538293	8055437
Stand 179	Binga	Lake Kariba	5	Domestic	17.5872	27.36155	538350	8055466
Stand 180	Binga	Lake Kariba	5	Domestic	17.58769	27.36188	538398	8055394
Stand 173	Binga	Lake Kariba	5	Domestic	17.58567	27.35925	538121	8055618
Taita	Binga	Lake Kariba	5	Domestic	17.5887	27.36201	538413	8055285

Water User Name	Location	Source	m3/day	Category	Southing	Eastings	X	Y
Plot 415	Binga	Lake Kariba	5	Domestic	17.58152	27.37198	539470	8056077
Plot 416	Binga	Lake Kariba	5	Domestic	17.58045	27.37134	539381	8056154
National Foods	Binga	Lake Kariba	5	Domestic	17.5803	27.37166	539434	8056212
Plot 441	Binga	Lake Kariba	2	Domestic	17.57935	27.37229	539506	8056316
Plot 418	Binga	Lake Kariba	2	Domestic	17.57938	27.37181	539451	8056308
Igloo	Binga	Lake Kariba	1	Domestic	17.57876	27.3717	539442	8056377
The Willows	Binga	Lake Kariba	1	Domestic	17.57823	27.371	539366	8056436
Stand 423	Binga	Lake Kariba	5	Domestic	17.57742	27.37063	539332	8056526
Stand 427	Binga	Lake Kariba	5	Domestic	17.57545	27.37079	539347	8056750
Stand 443	Binga	Lake Kariba	-	Domestic	17.57433	27.37232	539510	8056867
Stand 447	Binga	Lake Kariba	5	Domestic	17.57327	27.37449	539741	8056985
Stand 451	Binga	Lake Kariba	5	Domestic	17.5711	27.37483	539775	8057224
Stand 428	Binga	Lake Kariba	2	Domestic	17.57067	27.37789	539216	8057278
Stand 400	Binga	Lake Kariba	3	Domestic	17.57819	27.37231	539507	8056429
Kulizwe Lodge	Binga	Lake Kariba	15	Domestic	17.58814	27.35802	537981	8055339
Coventry	Binga	Lake Kariba	42	Domestic	17.6012	27.34414	536511	8053900
Sundown vila	Binga	Lake Kariba	5	Domestic	17.60774	27.3524	537387	8053181
Ambush Alley	Binga	Lake Kariba		Domestic	17.62665	27.32761	534752	8051088

Water User Name	Location	Source	m3/day	Category	Southing	Easting	X	Y
Zambezi Fisheries	Sinamwenda	Lake Kariba	1	Domestic	17.12299	27.86763	592298	8106634
C.E.F (Bartanaï Fisheries)	Sinamwenda	Lake Kariba	2	Domestic	17.1228	27.86759	592290	8106654
Chete Hunting Safaris	Chete	Lake Kariba	4	Domestic	17.34574	27.61634	565484	8082091
Chiobora Fishing Camp	Chibuyu	Lake Kariba	1	Domestic	17.11653	27.87879	593479	8107342
Mujeri Fishing Camp	Chibuyu	Lake Kariba	1	Domestic	17.08773	27.92965	598917	8110500
Chalala Fishing Camp	Chalala	Lake Kariba	4	Domestic	16.839	28.29297	637757	8137805
C.C.F (Gustrady)	Chalala	Lake Kariba	20	Domestic	16.84049	28.28822	637249	8137647
Balanced Foods	Chalala	Lake Kariba	2	Domestic	16.84015	28.28999	637430	8137691
Big Brother Enterp	Chalala	Lake Kariba	0	Domestic	16.839	28.28926	637359	8137806
Zambezi Fisheries	Chalala	Lake Kariba	6	Domestic	16.83767	28.28581	636994	8137955
Matemba fisheries	Chalala	Lake Kariba	20	Domestic	16.83738	28.28355	636750	8137991
Angelus Fisheries	Chalala	Lake Kariba	10	Domestic	16.83705	28.28248	636639	8138029
Deepland	Chalala	Lake Kariba	2	Domestic	16.83854	28.28672	6367090	8137858
Nyami Nyami D. C	Chalala	Lake Kariba	9	Domestic	16.83935	28.30168	638682	8137760
Brooklyn	Chalala	Lake Kariba	1	Domestic	16.82456	28.3212	640775	8139382
Bumi Hills	Bumi Hills	Lake Kariba	130	Domestic	16.80891	28.34836	643672	8141091
Bumi Hills (Workers' Quarters)	Bumi Hills	Lake Kariba	2	Domestic	16.80852	28.35996	644916	8141129
Kamativi National Service Camp	Mlibizi	Lake Kariba	5	Domestic	17.93333	27.07495	507939	8017188

Water User Name	Location	Source	m3/day	Category	Southing	Eastings	X	Y
Stand No. 5	Mlibizi	Lake Kariba	30	Domestic	17.9331	27.07546	507986	8017217
Stand No. 6	Mlibizi	Lake Kariba	50	Domestic	17.93167	27.07523	507966	8017374
Stand No. 4	Mlibizi	Lake Kariba	30	Domestic	17.93192	27.07606	508054	8017347
Stand No. 58	Mlibizi	Lake Kariba	20	Domestic	17.93429	27.07668	508118	8017084
Billy Knox	Mlibizi	Lake Kariba	40	Domestic	17.94243	27.07743	508201	801 6179
Sunover Beach	Mlibizi	Lake Kariba	60	Domestic	17.94361	27.08044	508517	8016051
Equinn	Mlibizi	Lake Kariba	20	Domestic	17.94404	27.08146	508626	8016002
Goba Lodge (Stand 136)	Mlibizi	Lake Kariba	5	Domestic	17.94536	27.08373	508865	8015855
Sinyman (Stand 138)	Mlibizi	Lake Kariba	5	Domestic	17.94599	27.08329	508819	8015787
Barner (Stand 139)	Mlibizi	Lake Kariba	5	Domestic	17.9461	27.0829	508779	8015773
Blume (Stand 140)	Mlibizi	Lake Kariba	5	Domestic	17.94615	27.08293	508779	8015768
Vandenbergh (Stand 167)	Mlibizi	Lake Kariba	5	Domestic	17.95322	27.07988	508457	8014989
Zinwa-(Binga)	Binga	Lake Kariba	734	Domestic	17.61547	27.34575	536637	8055324
Binga Crocodile Farm	Binga	Lake Kariba	2,000	Croc. Farm	17.58579	27.35657	537942	8055702
Binga Rest Camp	Binga	Lake Kariba	15	Domestic	17.58956	27.35955	533154	8055192
Chilila Lodge	Binga	Lake Kariba	42	Domestic	17.60101	27.41275	543800	8053914
Masumu River Lodge	Binga	Lake Kariba	30	Domestic	17.59158	27.42187	544774	8054954
Sijarira Game Park	Sijarira	Lake Kariba	3	Domestic	17.51192	27.49453	552499	8063747

Water User Name	Location	Source	m ³ /day	Category	Southing	Easting	X	Y
Chete Game Park	Chete	Lake Kariba	1	Domestic	17.34318	27.62317	566211	8082372
Gatche Gatche Irrigation Scheme	Gatche Gatche	Lake Kariba	2	Domestic	16.73624	28.93164	705926	8148624
Trek and Hunt Safari	Gatche Gatche	Lake Kariba	3	Domestic	16.73863	28.93592	706391	8148353
Chipungu Safaris	Gatche Gatche	Lake Kariba	15	Domestic	16.73962	28.94182	707019	8148233
UME lake Croc Farm	Ume	Lake Kariba	2,100	Croc. Farm	16.8511	28.43076	652460	8136390
UME lake Croc Farm	Ume	Lake Kariba	28	Domestic	16.8511	28.43076	652460	8136390
Tashinga National Park	Ume	Lake Kariba	5	Domestic	16.81805	28.45206	654724	8140002
Ume Camp	Ume	Lake Kariba	2	Domestic	16.82688	28.42918	652272	8139043
Umbabala Camp	Ume	Lake Kariba	2	Domestic	16.83224	28.43493	652889	8138449
Tiger Bay Hotel	Ume	Lake Kariba	40	Domestic	16.91344	28.4503	654458	8129447
Bullebe Safaris (Ume Camp)	Ume	Lake Kariba	6	Domestic	16.96097	28.44073	653356	8124228
CWF	Kariba	Lake Kariba	60	Crocodile Farm	16.56893	28.95078	708148	8157122
Charara Estate	Kariba	Lake Kariba	60	Irrigation (172ha)	16.56032	28.95531	708656	8168077
NAUZ	Kariba	Lake Kariba	30	Domestic	16.54872	28.95264	708370	8169355
Wild Heritage	Kariba	Lake Kariba	30	Domestic	16.56021	28.93459	706431	8168102
Ceruti	Kariba	Lake Kariba	30	Domestic	16.5509	28.9498	708063	8169117
Lamb's Lay	Kariba	Lake Kariba	10	Domestic	16.55208	28.94885	707974	8169005
Vundu Vay	Kariba	Lake Kariba	10	Domestic	16.55367	28.94721	707790	8168812
James Hilsgome	Kariba	Lake Kariba	5	Domestic	16.55367	28.94701	707757	8168812

Water User Name	Location	Source	m3/day	Category	Southing	Eastings	X	Y
Dawn View	Kariba	Lake Kariba	10	Domestic	16.55315	28.94752	707824	8168869
Trish Corks	Kariba	Lake Kariba	5	Domestic	16.55399	28.94644	707706	8168772
Hanga	Kariba	Lake Kariba	5	Domestic	16.55449	28.94622	707681	8168720
Detroit	Kariba	Lake Kariba	5	Domestic	16.55423	28.94585	707636	8168746
Dundly & Una	Kariba	Lake Kariba	5	Domestic	16.55453	28.94536	707587	8168718
Loury & Merle	Kariba	Lake Kariba	5	Domestic	16.55497	28.94545	707597	8168675
Avaolon	Kariba	Lake Kariba	10	Domestic	16.55544	28.94465	707528	8168584
Victor 4	Kariba	Lake Kariba	10	Domestic	16.55548	28.94432	707481	8168613
Ton Laundram	Kariba	Lake Kariba	1	Domestic	16.55604	28.94362	707406	8168558
Nzou Lodges	Kariba	Lake Kariba	8	Domestic	16.55617	28.94034	707042	8168541
Old Hararians	Kariba	Lake Kariba	30	Domestic	16.55671	28.94166	707194	8168479
Carribea Bay	Kariba	Lake Kariba	256	Domestic	16.53416	28.79952	692040	8171122
Nyanyana	Kariba	Lake Kariba	15	Domestic	16.54678	28.87937	700549	8169650
Lake Croc	Kariba	Lake Kariba	1,085	Crocodile Farm	16.54721	28.87354	699930	8169603
Zinwa	Kariba	Lake Kariba	15	Domestic	16.53893	28.86623	699157	8170527
Bream Farm	Kariba	Lake Kariba	432	Aquaculture	16.53011	28.86.67	698582	8171500
Lake Harvest	Kariba	Lake Kariba	48	Aquaculture	16.52499	28.85511	697982	8172077
UZLKRS	Kariba	Lake Kariba	5	Domestic	16.52509	28.84106	696478	8172082
Lomagundi	Kariba	Lake Kariba	30	Domestic	16.52534	28.83735	696094	8172056
Cutty Sark	Kariba	Lake Kariba	30	Domestic	16.53394	28.81848	694060	8171125

Water User Name	Location	Source	m ³ /day	Category	Southing	Easting	X	Y
Breezes	Kariba	Lake Kariba	30	Domestic	16.53251	28.81567	693772	8171280
Kariba Municipality (Breezes)	Kariba	Lake Kariba	12,500	Domestic	16.53636	28.81124	693287	8170875
Kariba Municipality (Zambezi)	Kariba	Lake Kariba	11,000	Domestic	16.53136	28.75743	687555	8171471
Sanyati	Kariba	Lake Kariba	60	Domestic	16.81728	28.76779	688380	8139812
Spurwing	Kariba	Lake Kariba	80	Domestic	16.72741	28.69291	680482	8149834
Forthergill	Kariba	Lake Kariba	20	Domestic	16.70215	28.66635	677670	8152650
		TOTAL	2,374,885	m ³ /day				