APPLICATION OF WEAP MODEL TO ASSESS FUTURE WATER DEMANDS AND WATER BALANCE OF THE MIDDLE KAFUE RIVER BASIN

By

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A dissertation submitted to the University of Zambia in partial fulfilment of the requirements of the degree of Master of Engineering in Water Resources Engineering

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AUTHOR’S DECLARATION

This dissertation was written and submitted in accordance with the rules and regulations governing the award of the Degree of Master of Engineering in Water Resources Engineering of the University of Zambia. I Aaron Kachunga, further declare that this dissertation has neither in part nor in whole been presented as substance of award of any degree, either to this or any other University. Where another people’s work has been drawn upon, acknowledgement has been made.

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CERTIFICATE OF APPROVAL

This dissertation of Aaron Kachunga has been approved as fulfilling part of the requirement for the award of the degree of Master of Engineering in Water Resources Engineering by the University of Zambia (UNZA).

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Sign: …………………3rd Examiner: …………………… Date………….…………

DEDICATION

This dissertation is dedicated to my parents, Gibson and Erida Kachunga, who have helped shape who I am today.

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TABLE OF CONTENTS

DEDICATION 1
ACKNOWLEDGEMENT 2
LIST OF TABLES 7
LIST OF FIGURES 8
ABBREVIATIONS AND ACRONYMS 9
ABSTRACT 11
CHAPTER 1: INTRODUCTION 12
  1.0 Background of the study 12
  1.1 Statement of the problem 14
  1.2 Justification 15
  1.3 Study Objectives 16
    1.3.1 Main Objective 16
    1.3.2 Specific Objectives 16
  1.4 Research Questions 16
  1.5 Significance of the study 16
  1.6 Scope of the study 18
  1.7 Organization of the thesis 18
CHAPTER 2: LITERATURE REVIEW 19
  2.0 Introduction 19
  2.1 Integrated Water Resources Management (IWRM) 19
  2.2 Fresh Water Crisis 20
  2.3 Zambian Water Situation 21
  2.4 Surface Water 22
  2.5 Allocation of Catchment Water 23
  2.6 Catchment Water Allocation 24
  2.7 WEAP Model Overview 25
  2.8 Water Permitting in Zambia 27
  2.9 Climate Change Perspective 28
  2.10 Climate Change – Zambian Perspective 28
  2.11 Green House Gas – Emissions and Agreements 29

2.12 Vulnerability of Agriculture Production and Hydropower Generation in Zambia to Climate Change. 30
2.12.1 Agriculture 30
2.12.2 Hydropower 31
2.13 Transboundary Aspects 32
CHAPTER 3: DESCRIPTION OF THE STUDY AREA 34
3.0 Introduction 34
3.1 Location 34
3.2 Physical Characteristics 35
3.2.1 Climate 35
3.2.2 Hydrology 35
3.2.3 Geology and Soils 36
3.2.4 Vegetation 39
3.4 Social Economic Activities 40
3.4.1 Population 40
3.4.2 Economic Activities 42
CHAPTER 4: METHODOLOGY 43
4.0 Introduction 43
4.1 Research Focus 43
4.2 Data Collection 43
4.3 Qualitative Data 44
4.4 Quantitative Data 49
4.4.1 Modelling Process 49
4.5 Data Analysis 51
4.5.1 Bias 51
4.5.2 Simulation of the Natural Flows 51
4.5.3 Climate Projections in WEAP 53
CHAPTER 5: RESULTS 55
5.0 Introduction 55
5.1 Modelling water allocation using WEAP 55
5.1.1 Water Availability in the Kafue Basin 55
5.1.2 WEAP Modelling 58
5.1.3 WEAP Model 63

5.2 Water Demand ______ 66
5.2.1 Multi-sectoral Uses of Water ______ 66
5.2.2 Environmental Requirements for Kafue River Basin and Climate variability 69
5.3 Climate Models ______ 69
5.3.1 Climate Model Analysis ______ 74
CHAPTER 6: DISCUSSION OF FINDINGS, CONCLUSION AND STUDY RECOMMENDATION ______ 81
6.0 Introduction______ 81
6.1Discussion of findings______ 81
6.1.1 Modelling water allocation using WEAP ______ 81
6.1.2 Effects of climate change on water allocation ______ 82
6.2 Conclusion ______ 84
6.3 Recommendations______ 85
REFERENCES ______ 87
APPENDICES ______ 91

LIST OF TABLES

Table 3- 1: Population Density of Zambia by Province....40
Table 3- 2: Population density in the Kafue Basin 41

Table 4- 1: Munyeke River at Mapanza Mission....47
Table 4- 2: Kafue River at Namwala Pontoon....47
Table 4- 3: Munyeke River at the Bridge....47
Table 4- 4: Bwengwe River 47
Table 4- 5: Chikumbwa River....48
Table 4- 6: Kaleya River....48
Table 4- 7: Magoye River 48
Table 4- 8: Kaleya River near the source....48
Table 4- 9: Kafue River at Kasaka....49

Table 5- 1: Gauge readings within the Kafue Basin 55
Table 5- 2: Discharge readings within the Kafue Basin 57
Table 5- 3: Different categories of water uses in the Kafue Basin 68
Table 5- 4: Short format used for the Combination of GCM'S and RCM's....70
Table 5- 5: CNRM-RCA4 Statistical Analysis....71
Table 5- 6: EC-EARTH CLMcom Analysis....72
Table 5- 7: ES CLMcom Analysis....73
Table 5- 8: Regional Climate Scenarios: Precipitation Information....73
Table 5- 9: Confidence Interval – Precipitation (mm)....75
Table 5- 10: Percentage Change (1980 – 2010)....78
Table 5- 11: Percentage Change (2046 – 2076)....78
Table 5- 12: Stream flow relative to reference period between the years 2046 - 2076 ...79
Table 5- 13: Temperature from the 1980 - 2010....79
Table 5- 14: Temperature between the period 2046 - 2076....80

LIST OF FIGURES

Figure 1- 1: Extent of Study Area 13

Figure 2- 1: Annual Average for freshwater 21
Figure 2- 2: Schematic View of WEAP Model 26

Figure 3- 1: Map Showing the location of the Kafue Basin 34
Figure 3- 2: Hydrological Map of the Kafue Basin 36
Figure 3- 3: Kafue Basin Geology 38
Figure 3- 4: Vegetation Map of the Kafue Basin 39
Figure 3- 5: Specific areas where different economic activities are concentrated 42

Figure 4- 1: Drones used during the study 44
Figure 4- 2: Drone flight 45
Figure 4- 3: Image of drone flight showing Kafue River 45
Figure 4- 4: Gauging station at Munyeke River at Mapanza Mission 46
Figure 4- 5: Discharge measurements at Namwala 49
Figure 4- 6 Automated Stations: Kafue river at Namwala 49
Figure 4- 7: Map Showing twenty-four Sub basins configured within Kafue Catchment 50
Figure 4- 8: Map Showing gauging stations within Kafue Basin 50
Figure 4- 9: Validated locations of the different water users within the Kafue Basin 52
Figure 4- 10: Definition of the ''REACH'' 53

Figure 5- 1: Kafue River inflow map 58
Figure 5- 2: Sum of yearly precipitation between simulated and observed values 59
Figure 5- 3: CNRM-CLMcom- Climate Model for the projected temperatures between the years 1900 to 2100 60
Figure 5- 4: CNRM-RCA4- Climate Model for the projected temperatures between the years 1900 to 2100 60
Figure 5- 5: EC-EARTH – Climate Model for the projected temperatures between the years 1900 to 2100 61
Figure 5- 6: EC-EARTH RCA4-Climate Model for the projected temperatures between the years 1900 to 2100 61
Figure 5- 7: CLMcom-Climate Model for the projected temperatures between the years 1900 to 2100 61
Figure 5- 8: RCA4-Climate Model for the projected temperatures between the years 1900 to 2100 62

Figure 5- 9: CLMcom-Climate Model for the projected temperatures between the years 1900 to 2100 62
Figure 5- 10: LR-RCA4- Climate Model for the projected temperatures between the years 1900 to 2100 63
Figure 5- 11: Modelled Kafue Basin 64
Figure 5- 12: Inflow into the ‘’Catchment Flat 1’’ of the Middle Kafue Basin 65
Figure 5- 13: Outflows below the ‘’ Lower Kafue’’ of the Middle Kafue Basin 65
Figure 5- 14: Drone image captured near Itezhi – tezhi Dam 66
Figure 5- 15: Drone image captured near Kafue Bridge 67
Figure 5- 16: Major Commercial users within the Kafue Basin 68
Figure 5- 17: Simulation of Inflow at Itezhi – tezhi Dam 74
Figure 5- 18: Modelled Stream flow between the years 2046 to 2076 75
Figure 5- 19: MRCP -4.5 Relative flows to baseline flows (1980 -2010) 76
Figure 5- 20: MRCP-4.5 Relative flows to baseline flows (2046-2076) 76
Figure 5- 21: RCP-8.5 Relative flows to baseline flows (1980 – 2010) 77
Figure 5- 22: RCP -8.5 Relative flows to baseline flows (2046 -2076) 77

ABBREVIATIONS AND ACRONYMS

CORDEX	Coordinated Regional Climate Downscaling Experiment
CLMcom	Climate Limited-area Modelling-Community
CNRM-CERFACS-CNRM-CM5	National Centre for Meteorological Research climate model developed by Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique
GIS	Geographic Information System
GCM	General Circulation Model
ICHEC-EC-Earth	Irish Center for High_End Computing, European Commisisom Earth system model.
ITCZ	Inter Tropical Convergence Zone
IPCC	International Protocol on Climate Change
ITT	Itezhi – Tezhi
IWRM	Integrated Water Resources Management
KGD	Kafue Gorge Dam
MOHC-HadGEM2-ES	Met Office Hadley Centre (Hadley Centre Global Environment Model version 2) coupled Earth System model
MPI-M-MPI-ESM-LR	Max Planck Institute for Meteorology Earth System Low Resolution Model.
RCA4	Rossby Centre regional atmospheric model
RCPs	Representative Concentration Pathways
SMHI	Swedish Meteorological and Hydrological Institute
WARMA	Water Resources Management Authority

WEAP	Water Evaluation and Planning Model
WRM ACT	Water Resources Management Act No. 21 of 2011

ABSTRACT

The ability to assess the catchment potential to satisfy water demands is vital for the management of the water resources. The current water allocation system in Zambia sits under the Water Resources Management Act No. 21 of 2011. The system needed to encourage optimal use of water resources as it provides prudent management, development, conservation, protection and preservation of the water resource in the country. The Kafue Basin as a whole experience priority water allocation conflicts on water permits due to high water demand for domestic, agriculture, hydro-power generation and industrial use. Water Evaluation And Planning Model (WEAP) provides an effective means of ensuring the water resource is being managed in an integrated and sustainable manner. The study focused on application of the WEAP Model to assess future water demands and effects of climate change on water allocation. Three different output scenarios which were used as inputs in the Water Evaluation and Planning (WEAP) model projected the intensity of climate change on the Kafue Basin and these output scenarios included: Two Climate scenarios i.e. MRCP 8.5 and MRCP 4.5 and one reference scenario from 1951 to 2021 which depicted the actual ideal conditions. The simulation showed that the Kafue Basin is highly affected by the effects of climate change which in turn results into decreased rainfall leading to decrease in the Kafue river flow, increased temperatures and evaporation. These effects result in low hydropower production from Itezhi –Tezhi and Kafue Gorge within the basin and lower the agricultural production hence the model that was applied would be used to effectively manage the water resources in the Kafue basin as a whole and could be used as a mitigating tool.

Key Words: Water Evaluation and Planning (WEAP) Model

CHAPTER 1: INTRODUCTION

1.0 Background of the study

One of the rivers that can be found entirely within Zambia is the Kafue River, which flows for over 1,600 kilometers in total length. Its source is located on the border between Zambia and the Democratic Republic of the Congo. It begins as a dambo about 120 kilometers to the west of Chingola town in Zambia. It then meanders southward and flows east through the Kafue Flats and Kafue Gorge before joining the Zambezi River near Chirundu District in Southern Province, Zambia (Zambia Advisor, 2017). The river is one of the Zambezi River's most important feeder streams, and its basin extends across an approximate area of around 155,000 km^2 in total. Along its channel, the Kafue River is home to a variety of purposes and activities, some of which include agriculture, mining, industry, municipal supply, household uses, and even recreation. The Kafue River can be broken down into three distinct sections: the Upper Kafue, the Middle Kafue, and the Lower Kafue. The Upper Kafue is comprised of the watershed that extends from the headwaters to Itezhi-tezhi, the Middle Kafue is comprised of the watershed that extends from Itezhi-tezhi to Kafue Gorge, and the Lower Kafue is comprised of the watershed that extends from Kafue Gorge to the point where the river confluences into the Zambezi (Booker Tate, 1994). The Middle Kafue, which is primarily comprised of Kafue flats, serves as the primary focus of this investigation.

The Middle Kafue ranges in elevation from 1300m to 300m above sea level, all the way to the end of the Kafue Gorge. The Kafue River flows 450 kilometers downstream of Itezhi Tezhi, the beginning of the Middle Kafue Basin, through the Kafue Flats, which cover an area of 7000 km^2 and are characterized by swamps and marshy land. The Kafue flats, which span parts of Zambia's Southern, Central, and Lusaka provinces, are made up of swamps, open lagoons, and are mostly flooded. The Middle Kafue River serves as a conduit for agricultural activities such as aquaculture, commercial, subsistence, and livestock farming, as well as the generation of hydro-electricity, all of which are vital to the national and regional economies of Southern Africa. Water demand in the Middle Kafue has resulted in competing needs among users such as domestic, agricultural, hydropower, and the environment. Several streams flow into the Kafue River, and it is from these streams that other water users draw. The extent of the study area is depicted in Figure 1-1.

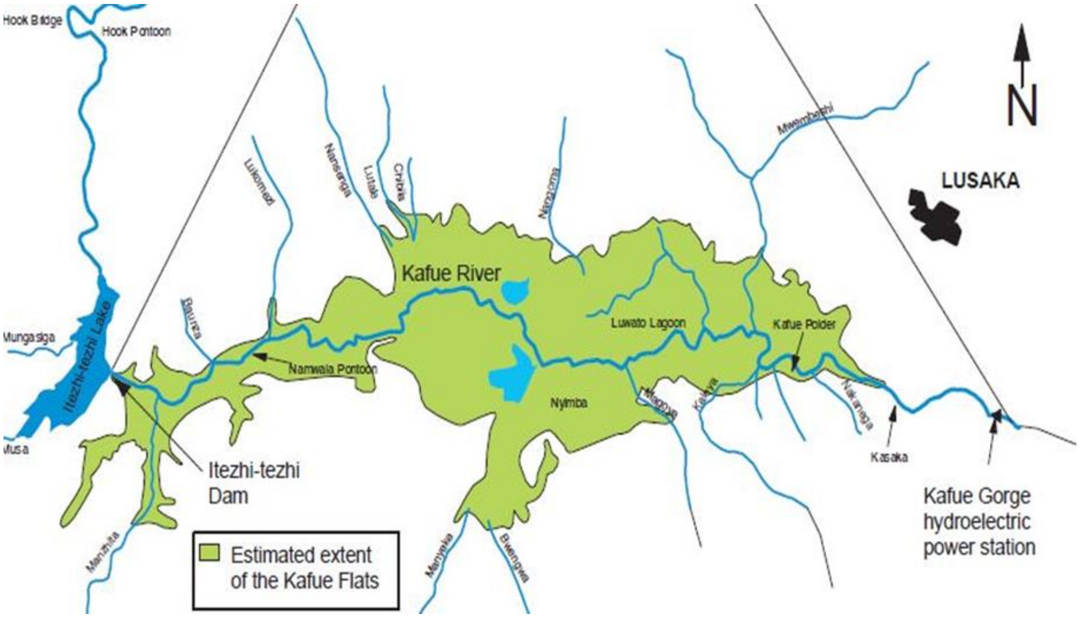


Figure 1- 1: Extent of Study Area

1.1 Statement of the problem

Population growth, economic development, degraded water quality, and climate change are all increasing competition for water resources. As a result, the issue of how water is allocated among users is rising to the top of the policy agenda in a number of countries, including Zambia. As water resources become scarcer, the value of allocation regimes that perform well across a wide range of conditions (both averages and extremes) can adapt to changing conditions at the lowest possible cost increases (OECD, 2019). Allocating water resources among the ever-increasing number of different users has been a challenge, and it cannot be accomplished effectively without the use of appropriate technologies to meet the increased demand. Water resources have not been properly managed, resulting in insufficient supplies for various purposes, insufficient information for decision making, and inefficient resource use, necessitating the use of tools that simulate water allocation, climate change scenarios, and water balances.

Thus, the study was carried out to investigate the use of a water evaluation and planning system model to assess future water demands and water balance in Zambia's middle Kafue river basin.

1.2 Justification

According to the Water Resources Management Act No. 21 of 2011, there is a need to plan for the sustainable and rational use, management, development of water resources based on community and public needs and priorities, within the framework of national economic development policies. In accordance with this mandate, one of the key factors in developing water allocation plans is catchment planning, water allocation planning and improvement. Water allocation priorities differ from place to place, necessitating the use of appropriate models in each case for maximum efficiency (Bangas et al. 2012).

The ability to assess catchment potential to meet water demands is critical in order to plan for the future and make sound decisions (Arranz and McCartney, 2007). The current water allocation system must encourage efficient water use because improvements in allocation practices may increase the value of water resources to communities. As a result, the use of modeling tools would provide an effective means of ensuring that the water resource is managed in an integrated and sustainable manner. With the help of modeling tools in analyzing the impact of alternative water allocation policy scenarios, it is possible to meet competing demands while also achieving positive economic and environmental outcomes. Water allocation models based on simulation employ mass balance principles to allocate water resources in a river system (Braun, 2014). One of the most important goals of water management is to match or balance the demand for water with its availability through appropriate water allocation arrangements (DFID, 2019).

The well-known issue of climate change, which has affected the levels of water generation and caused a number of economic and environmental concerns is essential to the existence of sustainable water management (UN,2022). In light of this significant divergence, the model explores how to maintain a balance of efficient water management practices in the face of climate change consequences.

1.3 Study Objectives

1.3.1 Main Objective

The primary purpose of this research was to apply the WEAP Model in assessing future water demands and water balances including the effects of climate change in the Middle Kafue basin.

1.3.2 Specific Objectives

i. To apply WEAP model in water allocation within the Middle Kafue Basin.
ii. To assess effects of climate change on water allocation
iii. To explore the various sustainable ways of water allocation in the basin

1.4 Research Questions

i. What are the various applications of WEAP model in water allocation?
ii. What are the effects of climate change on water allocation?
iii. What are the various sustainable ways of water allocation in the basin?

1.5 Significance of the study

The provision, generation, and extraction of water are determined by modeling water supply to monitor the social, economic, and wellness of many people residing in a certain area under consideration. By integrating water resources planning into the research, the

WEAP model helped to provide a thorough, adaptable, and user-friendly framework for policy analysis.

Dealing with uncertainty in the present as well as the future is necessary for sustainable water management. Life is full of uncertainties, and the further they are, the harder they are to deal with. Future water management uncertainty manifests itself in a number of ways, including Natural variability which is the study of cyclical changes in the environment that may or may not be caused by climatic change or other external factors. The effect of climate change and natural variability may be difficult to separate in expected extremes, such as precipitation and river runoff. Additionally, natural and socioeconomic processes interact and create new uncertainties. For example, land subsidence brought on by excessive groundwater extraction is a contributing factor in highly populated deltas.

The thematic and contextual bodies of knowledge both benefited greatly from this study in a number of ways, including:

i. Effective water distribution to the general populace, which needs water for numerous purposes. The study guarantees to offer a foundation for efficient water distribution to the general population. This examines methods for ensuring that each user has adequate access to water.
ii. Builds stakeholder participation for efficient water management. The study creates a model that provides an integrated approach to successful water management in the study region, allowing for sustainable water usage in the face of climate change and building a resilient water management system for the area.

According to the study's setting, this research has a highly important position for the local population through knowledge provision, for policymakers, for academics, and for authors since it fills a knowledge vacuum and provides a thematic field of knowledge.

1.6 Scope of the study

The focus is on the application of WEAP model to assess future water demands and water balance of the Middle Kafue River Basin.

1.7 Organization of the thesis

The first chapter of the thesis provides an overview of the research's historical context, highlighting the Kafue basin and its further extension into the Middle Kafue Basin. It also focuses on the study's goals and relevance, and it concludes by outlining the research's scope.

Issues with watershed water allocation optimization, integrated water resources management, the fresh water crisis, and WEAP models used in water resources management are highlighted in Chapter 2, which concludes with reflections on climate change.

The Middle Kafue Basin's geographic position as well as its social, economic, and physical characteristics are described in Chapter 3. In Chapter 4, data sources, types, and analysis techniques are discussed in relation to modeling water allocation. The outcomes are presented in Chapter 5 as the established objectives.

Chapter 6 discusses the research findings and offers suggestions on how the model could be used to its fullest potential.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

The catchment water allocation and effects of climate change are reviewed in this chapter. It starts off with a global overview of surface water before focusing on the catchment water allocation of the middle Kafue basin in Zambia's Southern Province. It also emphasizes the use of the modelling tool WEAP (Water Evaluation and Planning System) for catchment water distribution. The consequences of climate change on agricultural output and hydropower production are also discussed in this chapter.

2.1 Integrated Water Resources Management (IWRM)

According to its definition, IWRM is a process that aims to encourage the integrated development and management of water, land, and related resources in order to optimize the resulting economic and social welfare in an equitable way without jeopardizing the sustainability of important ecosystems (GWP, 2000). The IWRM strategy aims to coordinate the management of water resources across many sectors and interest groups. It places a focus on participation in national policy and policy making processes, fostering good governance, and developing efficient institutional and regulatory frameworks that result in more than just sustainable outcomes (GWP, 2000). The Dublin Principles, which aim to promote changes in the concepts and practices crucial to improved water resources management were developed through an international consultative process that culminated in the International Conference on Water and the Environment in Dublin, 1992, among the general principles and guidelines of IWRM (GWP, 2000). The four guiding Dublin statement's concepts are listed below:

1. A limited and fragile resource, fresh water is necessary to support life, development, and the environment. By integrating social and economic growth with the preservation of the natural ecosystem, effective management of the water resources should aim to support life and livelihood throughout the catchment region.
2. Users, planners, and policymakers should all be involved in the creation and management of water resources. This strategy emphasizes the value of making decisions at the most basic levels, fully consulting the public, and including users in the development and implementation of water projects. As a result, policymakers and the general public will become more aware of the significance of water.
3. Water provision, management, and protection are all heavily influenced by women. This principle emphasizes how institutional planning for the development and administration of water resources has considered women's roles as water providers, users, and protectors of the environment.
4. Water should be regarded as an economic good because it has a financial worth in all of its competing uses. This principle emphasizes the significance of managing water as an economic good in recognizing the fundamental human right to affordable access to safe drinking water and sanitary facilities.

2.2 Fresh Water Crisis

One of the most pressing issues is the global trend of water scarcity, extreme weather and climatic circumstances which have an impact on fresh water sources, lowering their quality and making them more difficult to acquire. Therefore, it is essential to manage water resources holistically to ensure that everyone has access to fresh water every day and every year (Bishawjit and Luisa, 2015). Compound annual averages for freshwater are displayed below (Figure 2-1).

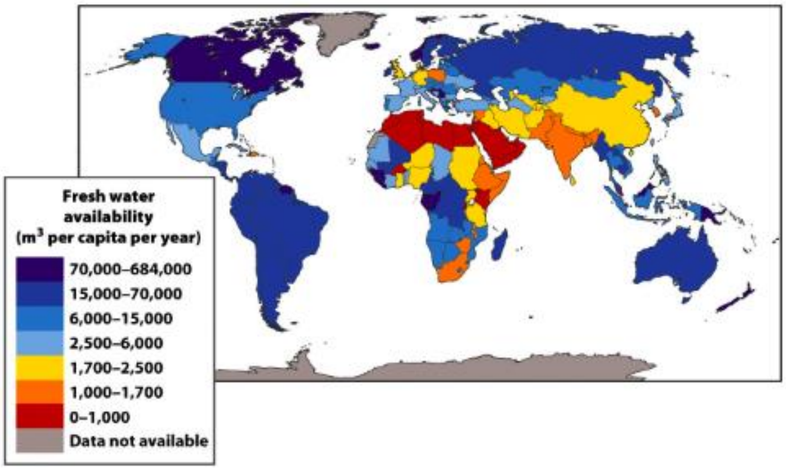


Figure 2- 1: Annual Average for freshwater

(Source; Food Agriculture Organization AQUASTAT, 2018),

Up to 90% of freshwater withdrawals in developing nations are used for agriculture, but as economies grow, cities expand, industrial uses and energy production all increase water demands, making it more difficult to allocate water resources wisely (FAO,2018).

2.3 Zambian Water Situation

Zambia's water resources provide critical services that aim to reduce poverty, improve public health, and increase food security, resulting in long-term economic, social development and a healthy environment for the country. Water is becoming scarce, and the World Economic Forum has named the water supply crisis as one of the top three global risks (WWF, 2016). According to Nkhuwa el, (2013), drought in the country has impacted agriculture and other sectors, causing challenges and opportunities for further economic advancement. High temperatures and the average annual potential evapo-transpiration, which ranges from 1394mm to 1892mm with an average of 1574mm, have hampered water availability in Zambia. The country is experiencing a hydrological deficit of 100mm to 1100mm per year, causing evapo-transpiration to be greater than precipitation (Braun, 2014).

2.4 Surface Water

More than one billion km^3 of surface water covers the majority of the earth, but the vast majority of that water is in forms inaccessible to land-based or freshwater ecosystems. Less than 3% of this total is fresh enough to drink or irrigate crops, and more than two-thirds of this total is locked in glaciers and ice caps. Freshwater lakes and rivers hold up to 100,000 km^3 of water globally, which is less than one-tenth of all water on the planet (Dahm, 2001). Fewer than ten countries control 60% of the world's available fresh water supply, including Russia, Brazil, China, Indonesia, Canada, the United States of America, India, Columbia, and the Democratic Republic of the Congo, with highly significant local variations within each of these countries (Wayne, 2013). Because of the abundance of fresh water, the United States has a comparative economic advantage in goods that require freshwater, making freshwater a geopolitical resource in the same way that oil is (Mugatsia, 2010). These valuable fresh waters are under-monitored, impeding progress toward national and international development goals (McCartney, 2017).

Understanding how water is used by different sectors can help with planning for the management of water resources since fresh water is required for human needs such as drinking, agriculture, sanitation, and manufacturing. In many developing countries, irrigated water accounts for almost 90% of total fresh water withdrawals from the agricultural sector, which is the largest user of water resources globally (Wayne, 2013). As a result, in a world where demand is rising, water must be distributed in ways that are effective, equitable, and sustainable.

2.5 Allocation of Catchment Water

A catchment is a region where water is gathered by the environment and eventually flows into the groundwater system, a river, stream, lake, or ocean (Farrell, 2011). Rain and surface runoff eventually result in water entering a catchment. There are a variety of water consumers in catchments, including urban areas, mining operations, agricultural uses, industry, and power generating (Roberto Arranz, 2016). To guarantee a constant supply for the users, the catchments must be carefully managed. To maintain the wellbeing of aquatic ecosystems and guarantee a sustainable and effective use of freshwater resources, integrated water resources management policies and supply systems are required (Almestad, 2015). To assess and recommend the optimal management practices for maximizing benefits for specific users, analysis tools such WEAP models are utilized (Ju'zo1 and Lid'en, 2010). It is crucial that water demand and usage are managed efficiently by the authorities responsible for the mandate given the limited availability of water resources (Ashton, 2013). Decision support systems are essential because water allocation decisions are difficult and complex, requiring political will and practical techniques to choose between opposing interests and goals (Robb, 2001). Water management strategies need to deal with the underlying issues that lead to water scarcity and ecological degradation (Braun, 2013). The sustainability of water resources and the environment, as well as economic effectiveness and social progress, depend on water conservation and demand management (Herbertson, and Tate ,2001). The entire downstream of the system is affected by the water that is removed from these rivers, streams, and lakes (Cap-Net, 2008). Therefore, it is necessary to predict the amount of water in a river system, and this projection offers a crucial planning tool for adjusting to variations in the availability of water in a watershed. The preservation of the environment for future generations and the provision of safe and equitable water access for all users depend on planned water allocation (CSIRO, 2013). Due to the growing inter-sectoral needs, effective and sustainable water allocation policies must be devised in order to meet the competing demands and produce favorable economic and environmental results. An efficient tool for water allocation, supply and demand analysis, and scenario evaluation of water management can be obtained by using WEAP as a decision support tool (Mugatsia, 2010). The WEAP System model makes it possible to assess, plan, manage, and develop water resources (Arrannz, 2016).

2.6 Catchment Water Allocation

To effectively manage water resources, decision-makers must deal with dynamic water resources and scientific uncertainty, as well as strong and often conflicting stakeholders. Dealing with conflicting stakeholders leads to the realization that current water allocation systems do not encourage optimal water use, and thus improvements in allocation practice could increase the value of water resources (Robb, 2001).

Strategic water allocation is difficult to define. Examining a given situation and determining what is optimal necessitates a comparison to stated goals. Understanding a resource and all of its associated existing and future environmental and economic values, setting clear objectives, and selecting management options that optimize outcomes across a suite of objectives are all part of optimal water allocation.

2.7 WEAP Model Overview

WEAP (Water Evaluation and Planning) is computer aided multi-scale water planning and allocation modeling tool. WEAP models are adequate for evaluating and proposing the best management strategies to maximize benefits for a given number of users in a given catchment under given objectives and functions (Ju'zo1 and Lid'en, 2010). The WEAP System model allows for the assessment of water resource development planning and management issues (Arrannz and MacCartney ,2017). WEAP can be used as a decision support tool to help with water allocation, supply and demand analysis, and evaluating water management scenarios (Mugatsia, 2010). WEAP is used to effectively manage water resources through integrated water resource planning and evaluation. WEAP structure includes five views that provide a user-friendly interface (SEI, 2013) and below are the three main views for the purposes of illustrations:

i. Schematic View: This is a window that displays the physical structure of the supply and demand graphically (Figure 3), where features can be created by dragging and positioning. Background layers in this view window are GIS vector and raster files.

ii. Data View: This window displays relationships between system elements, allowing variables and relationships to be created by entering assumptions and projections using mathematical expressions.

iii. Results: As model outputs, detailed and flexible tables, maps, and charts referring to supply and demand are displayed in this window.

Notes: This is the window where data and assumptions are documented. It acts as a word processing tool for the purposes of referencing and documenting details in data view. (Figure2-2)

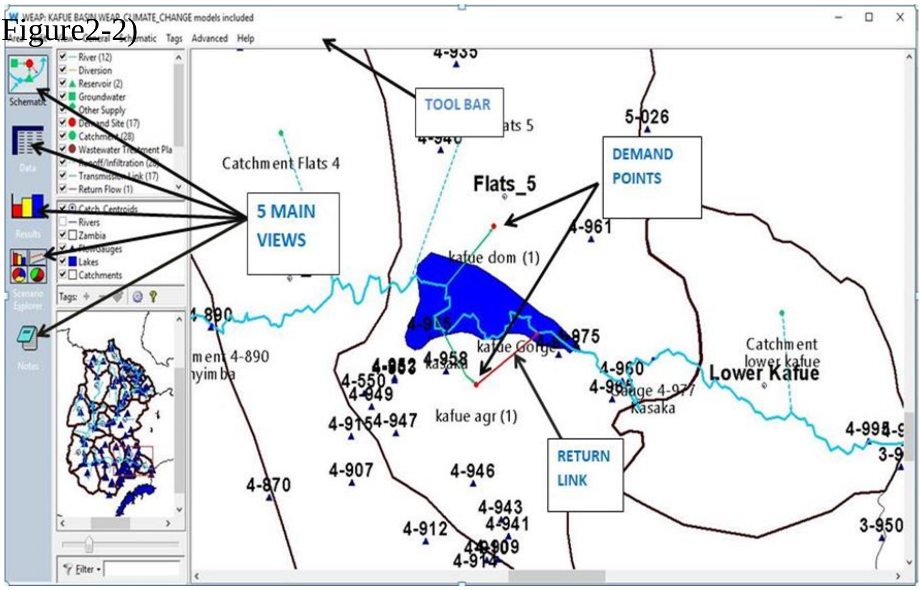


Figure 2- 2: Schematic View of WEAP Model

WEAP is based on water balance principles, making it applicable to a wide range of issues such as sectoral demand analysis, water permitting and allocation priorities, water conservation, groundwater and streamflow analysis, hydropower generation, water quality, and rainfall runoff and base flow analysis. WEAP includes features such as scenario-based analysis, a graphical interface based on GIS, user-defined variables and equations, fast solution algorithms, and an easy-to-use interface (SEI, 2013). WEAP provides a comprehensive system analysis tool for maintaining water demand and supply that can be used for water development and management by taking competing users from various sectors into account.

2.8 Water Permitting in Zambia

The Water Act of 1949 was abolished and replaced by the Water Resources Management Act No.21 of 2011, which also formed the Water Resources Management Authority (WARMA). WARMA's primary mission is to manage, develop, conserve, protect, and maintain the country's water resources (WRM Act No 21 of 2011).

Through the promotion and adoption of an integrated multi-sectoral strategy for the management of water resources in Zambia, WARMA is able to exert control over all of the country's water resources, as required by the Water Resources Management Act. The Water Resources Management Authority is responsible for ensuring that water resources are used in a manner that is both sustainable and sensible. This is accomplished by ensuring that a sufficient amount and quality of water is available for a variety of uses. The Water Resources Management Act included measures that would govern the use of water in Zambia by considering or issuing water licenses. These provisions were included as part of the act because they were deemed necessary. WARMA is given the authority, in accordance with the Water Act, to issue water permits and licenses, which enable the holder the permission to use water for a variety of reasons.

The Water Resources Management Authority is charged with the responsibility of preserving, conserving, and protecting Zambia's ground and surface water resources, as well as regulating the abstraction, allocation, use, development, and management of water resources in a manner that is sustainable. This mandate can be found on the Water Resources Management Authority website (http://www.warma.org.zm). The procedure of obtaining a permit starts with the submission of application forms for a variety of water uses and continues up until the point where the permission is approved. The Act specifies that water may be utilized for domestic purposes, environmental purposes, educational and research activities, municipal purposes, industrial purposes, agricultural purposes, mining purposes, navigational purposes, and the supply of water in bulk, among other uses.

2.9 Climate Change Perspective

The Earth's climate system is dynamic on all spatial and temporal scales, with consequences felt around the world. The specific industries that feel the repercussions of this phenomenon shift from place to region. The early recognition and comprehension of human-made effects on Earth's climate is crucial to the fate of humanity and nature, making climate change the preeminent scientific, economic, political, and moral concern of the 21st century (Hansen et al. 2012). Climate change currently underway includes higher temperatures, altered rainfall patterns, increasing sea levels, and acidity of the oceans.

2.10 Climate Change – Zambian Perspective

Since 1960, Zambia's average annual temperature has risen by 1.3 degrees Celsius, and another 1.2 to 3.4 degrees Celsius are expected to be added by the 2060s, with the southern and western regions experiencing the most rapid warming (McSweeney et al. 2010). The effects of climate change have posed numerous difficulties for the administration of the nation's water supply. Due to an imbalance in the distribution of the country's surface waters, some parts of the country, particularly the south, confront water scarcity.

Most climate models used to make climate projections for Zambia agree on the following (Irish Aid, 2015):

i. projected annual temperature increase of 1.2 °C to 3.4 °C by the 2060s and of 1.6 °C to 5.5 °C by the 2090s.
ii. By the 2060s, the average annual temperature is expected to rise by 1.2°C to 3.4°C, with warming expected to be more severe in the south and west.
iii. A decrease in yearly precipitation and a rise in the frequency and severity of extreme rainfall events during the rainy season.
iv. Between 1960 and 2006, there was a sharp increase in the average annual number of hot days and nights, with both reaching 43 °C.
v. Less precipitation is expected in the south and centre of the country (Regions I and II), according to Zambia's National Adaptation Programme of Action (NAPA).
vi. Since 1960, annual rainfall in Zambia has dropped at a rate of 1.9 mm per month, mostly due to drier Decembers and Februarys.

2.11 Green House Gas – Emissions and Agreements

Agreements to keep global warming well below 2 degrees Celsius and to pursue efforts to even aim for a 1.5 degrees Celsius limit have been reached, but there is still a huge gap between the countries' greenhouse gas reduction targets in different regions and their progress toward adequately implementing the Paris agreement in national legislation, which has an effect on climate change (UNEP, 2017). Emissions of greenhouse gases have roughly doubled since the early 1970s and are projected to increase by more than 70% from 2008 to 2050. Since the majority of historical greenhouse gas (GHG) emissions stem from the Organisation for Economic Co-operation and Development's (OECD's) wealthier member states, economic activity in these nations has largely been responsible for the steady increase in GHG concentration that has occurred since the industrial revolution and is having an effect on climate change (OECD, 2008).

2.12 Vulnerability of Agriculture Production and Hydropower Generation in Zambia to Climate Change.

2.12.1 Agriculture

Commercial and subsistence farming both play a significant role in the economy of the Kafue Basin. Farmers who cultivate lands between 5 and 20 hectares in size are considered medium-scale, while those who cultivate lands between 0.1 and 4.99 hectares are considered small-scale. Robb (2001) estimates that 32% of Zambia's land is used for agricultural purposes, and that 70% of the country's farms are considered to be of the small-scale variety. Most smallholder farmers only have enough yield from a single harvest to meet their own needs and the needs of the market. The vulnerability of small-scale farmers is exacerbated by the fact that most of them grow maize, which must be watered by hand and from the rain (Ndirima et al. 2007). Agriculture in Zambia has been impacted by rising temperatures and a drop in normal rainfall. Production of maize fell by 42% from the typical annual rate as a result of adverse weather conditions in 2001 and the subsequent growing season (Johannes, 2004).

One of the economy's most vital pillars, agriculture is extremely sensitive to weather conditions. Since the first Intergovernmental Panel on Climate Change (IPCC) Assessment Report was published in 1990, a great deal of work has been done to better understand the effects of climate change on agricultural systems. By collecting useful data, creating useful models, and observing the changes in climate and its repercussions, there has been significant progress in the knowledge on the impacts of climate change. Changes in agricultural and livestock output as a result of climate change will cause shifts in the most lucrative production strategies for any given region (McSweeney. 2010)

2.12.2 Hydropower

Hydropower is a cornerstone of renewable electricity production and a source of social and economic growth in every region of the world. The majority of the water in northern Zambia is put to non-consumptive use in hydropower generation, while the remainder is used for things like agriculture, domestic water, and industry (Mweemba and Nyambe,2013). Climate change, however, threatens hydropower and its environmental implications. Creating a sufficient head for the turbines to turn requires dams to be built as part of every hydropower project. Because these water development projects have far-reaching and often unpredictable ecological and environmental repercussions, the unique characteristics and design of each hydropower plant are crucial in evaluating their susceptibility to damage. Adaptation measures must consider the relative resilience of different reservoirs to the effects of climate change (Martin M. Bunyasi, 2012). Since run-of-river hydropower plants (also known as river power plants) employ the natural water flow of a river or of a diversion canal, any change in the hydrologic regime, which could be caused by climate change, will have direct consequences for hydropower generation. Over time, operations will be impacted by the slow but steady shifts in temperature, precipitation, etc., as well as the potential shifts in the frequency and intensity of extreme weather occurrences.

Over 99% of Zambia's electricity comes from hydropower, making it one of the most hydropower-dependent countries in sub-Saharan Africa (UN,2022). For this reason, hydropower already plays a crucial role in many African locations, and its importance will only grow in the years to come. However, hydropower can be impacted by a changing climate because of the way precipitation and temperature in a catchment area affect river flow. Additionally, climate change may increase the likelihood of extreme flood events or droughts, which raises the costs and risks associated with hydropower projects. Another potential issue that climate change could bring about is sedimentation, which can cause obstructions due to fallen logs, turbine abrasions, and decreased efficiency due to decreased storage capacity of the reservoirs.

Both drought and flooding have had a negative impact on Zambia's hydro-electric power output, but the former has had a greater economic impact, decreasing the country's power potential. There have been negative effects on the Zambezi River basin as a result of the impact of rainfall changes on run-off, reservoir storage capacity, and hydropower potential. Agriculture and hydroelectric power generation were two of the hardest hit industries when a terrible drought hit the riparian states of the Zambezi basin in the 1991/92 rainy season. (UN, 2017).

There is a dynamic relationship between the quantity and timing of water resources on the Kafue flats, which leads to conflicts among water users on the Kafue basin. Hydro-power generation and commercial agriculture rely on an adequate quantity of water resources, while environmental flows meant for ecosystem functions depend on the timing of the quantity. For this reason, the Water Resources Management Act No. 21 of 2011 prioritizes domestic water usage above all other uses, including conservation and hydropower generation, the latter of which is especially important in the Kafue basin for supporting mining and commercial farming (Chomba, and Nkhata, 2016).

2.13 Transboundary Aspects

The Water resource managers, such as utilities and regional policymakers, face new difficulties as a result of climate change. Ecosystems, biodiversity, agriculture, food security, land use, forestry, water supply and sanitation, health, urban settlements and infrastructure, energy supply, and electricity generation are all impacted by the increased vulnerability of freshwater resources. Furthermore, this would have an effect on regional water supply and accessibility, leading to regional water crises, which in turn would lead to destabilization, violence, and war, which would disproportionately affect the poor and the powerless. As a result, social, ecological, and economic pressures can be assessed in full when evaluating the effects of climate change on water resources at the basin or catchment level. Social pressures such as population increase, land-use change, demographic change (including migration), and urbanization all have unavoidable consequences on water availability and access, and hence must be considered. Vulnerable nations will continue to feel the detrimental effects of climate change unless they adopt more flexible management methods and strengthen their institutions. Institutional capacity, especially in the context of governance, that is responsive, accessible, inclusive, and equitable, and that can promote change at the municipal, provincial, national, and regional levels must be provided to facilitate effective adaptation across these scales. Transboundary collaboration is also essential to reduce water resource vulnerability (Braun, 2014).

CHAPTER 3: DESCRIPTION OF THE STUDY AREA

3.0 Introduction

The research location, as well as the physical and socio-economic aspects of the area, are discussed in this chapter.

3.1 Location

Zambia's Kafue basin is a key Zambezi tributary. Located entirely in the Zambezi basin, the Kafue Basin is 156,995km^2 and is 1,500 km long. The Kafue basin's headwaters (Figure 3-1) begin in Zambia's North Western Province near the DRC border and flow south across the Copperbelt to Itezhi-tezhi. Upper, Middle, and Lower Kafue make up the river. The Upper Kafue runs from the headwaters to Itezhi-tezhi, the Middle Kafue runs from Itezhi-tezhi to Kafue Gorge, and the Lower Kafue stretches from Kafue Gorge to the Zambezi confluence. The focus of study which is the Middle Kafue is 1,300m to 1,000m above sea level from the Kafue Gorge to the Zambezi confluence.

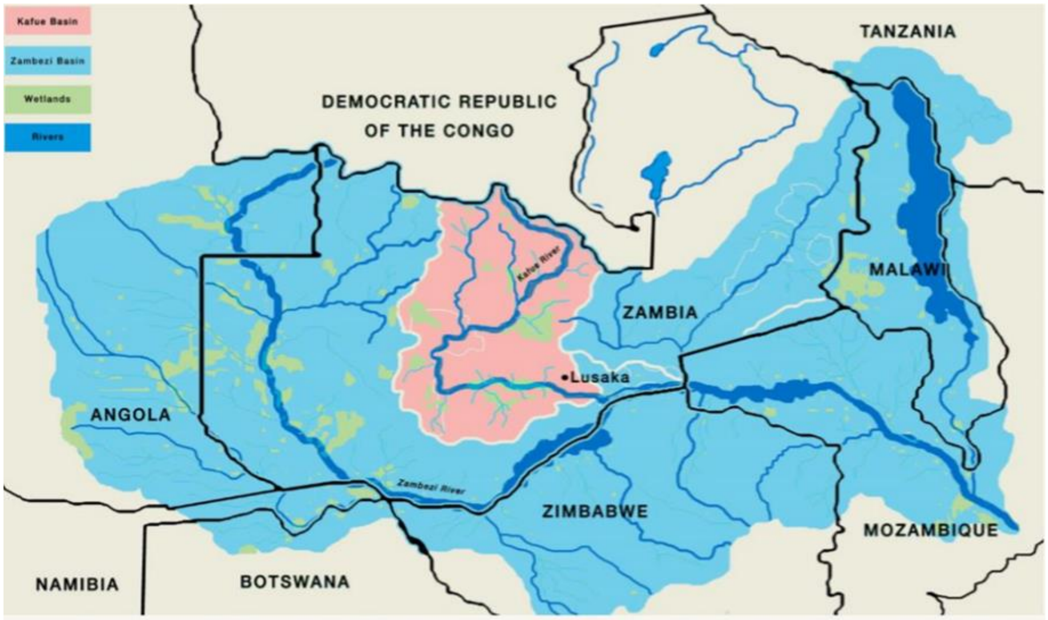


Figure 3- 1: Map Showing the location of the Kafue Basin

(Source: Brief 2016)

3.2 Physical Characteristics

3.2.1 Climate

There are two distinct seasons in the Kafue Basin; the rainy season and the dry season. The months of May through October are considered to be the dry season, whereas the months of November through April are considered to be the wet season.

Intertropical Convergence Zone (ITCZ) low-pressure systems bring rain to the Kafue watershed by focusing the Trade Winds in one area. The annual precipitation in the basin varies from 1,300 millimetres in the north to 800 millimetres in the south. The monthly and yearly rainfall values throughout the basin fluctuate slightly in average values due to natural changes in rainfall, which are more important in the south and west, where the frequency and duration of dry spells are greater than the rainy periods.

3.2.2 Hydrology

The basin of the Kafue River encompasses a total area of 155,948 km^2 of land. The Kafue River Basin is primarily fed by the waters of the Mwambashi River, the Luswishi River, the Lunga River, and the Kafulafuta River. The Middle Kafue basin is the subject of this study and is characterized by flood plains and wetlands that encompass approximately 6,500 km^2 and have a slope of less than 5 cm/km. The hydrological Map of the Kafue Basin is displayed in figure 3-2.

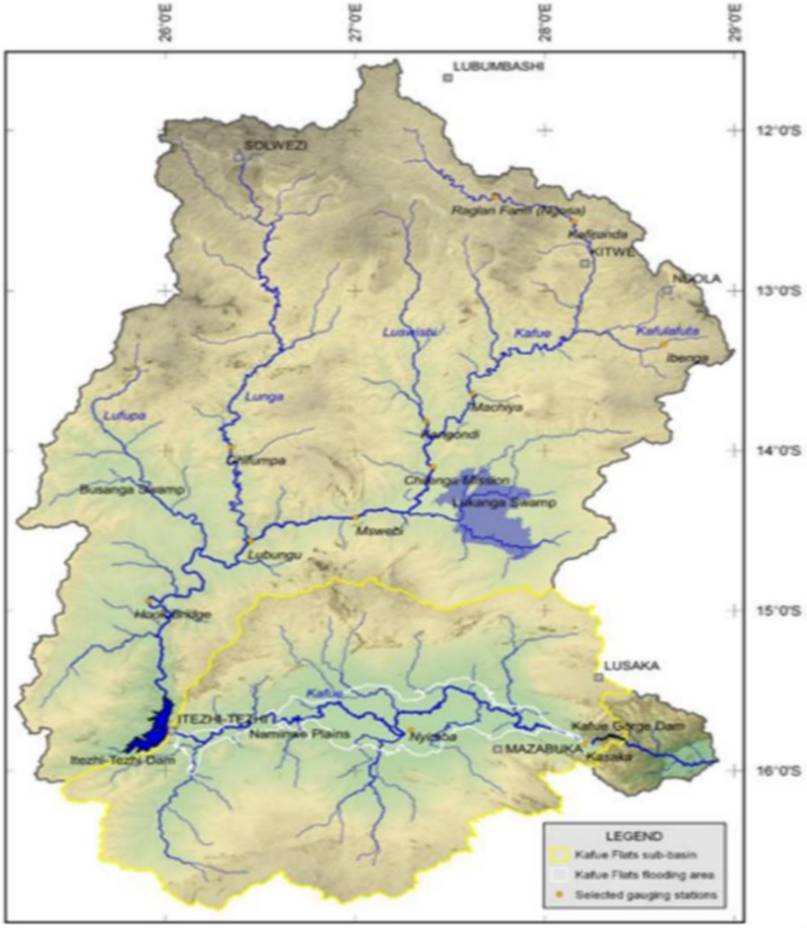


Figure 3- 2: Hydrological Map of the Kafue Basin
(Source: Brief, 2016)

According to the records, the mean annual flow inside the Kafue basin only accounts for around 6.2% of the mean annual average rainfall of 1057 mm that falls over the catchment.

3.2.3 Geology and Soils

The majority of the soils in the basin are made up of alluvial clays, and because of the changes in the hydrological conditions, the soils range from very fine black clays to black clays that are hard and dry to depths of more than 30 centimetres towards the conclusion of the dry season (Ndirima, 2007). The in-depth geological map can be seen down below

(Figure 3-3) in its entirety. Additionally, the hydrological conditions along with a few selected gauging stations are depicted on the map. These gauging stations were maintained by the Department of Water Affairs (DWA), which is now known as the Department of Water Resources Development (DWRD) and falls under the Ministry of Water Development and Sanitation.

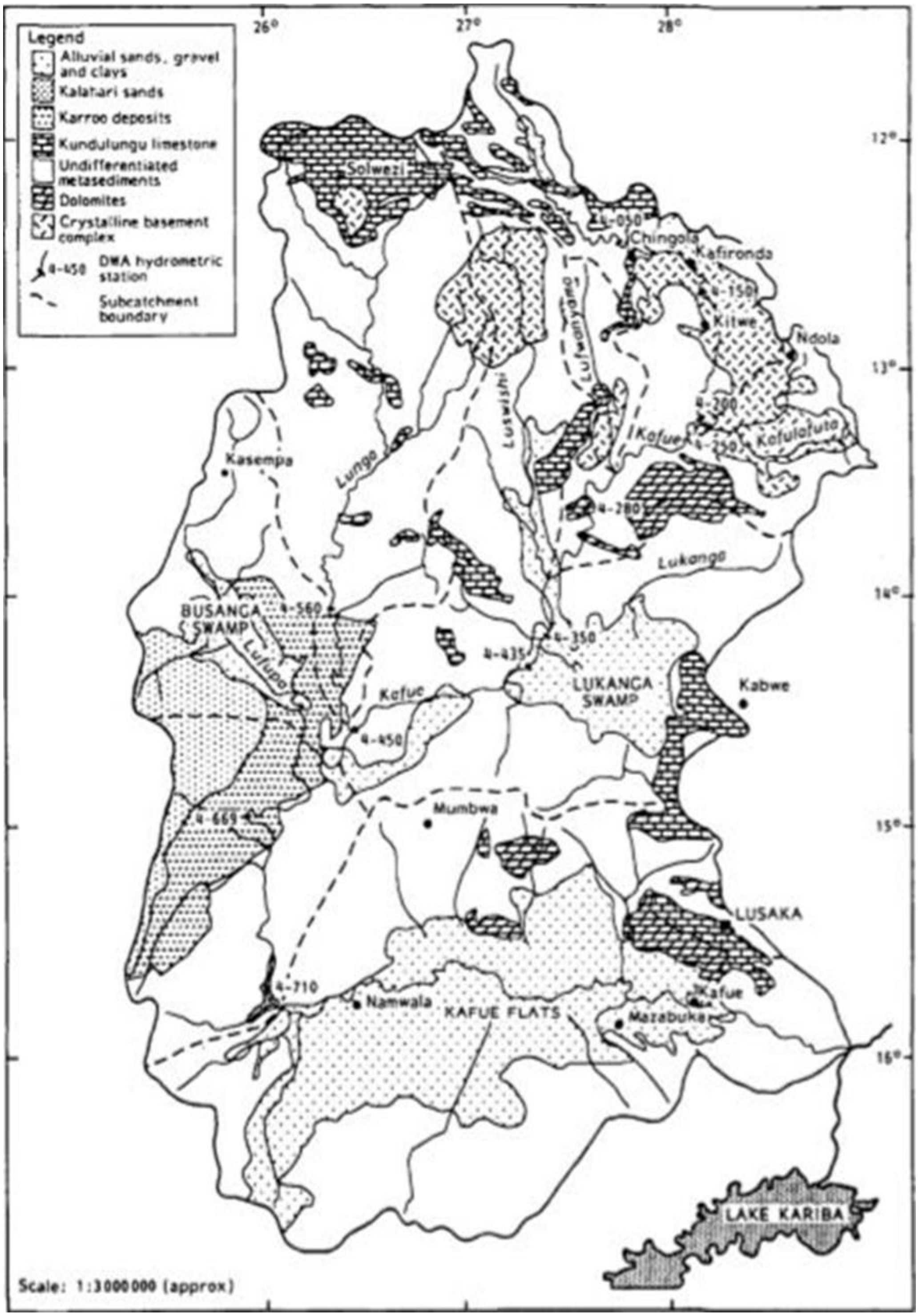


Figure 3- 3: Kafue Basin Geology

(Source: Natural Resources Forum, 1994)

3.2.4 Vegetation

The Kafue flats characterize the Middle Kafue Basin, which lies between the Itezhi Tezhi Dam and the lower Kafue Gorge. The vegetation found along the Main River channel is grasslands, and the area immediately downstream of the Itezhi tezhi dam has some features of Kalahari woodlands, as shown in Figure 3-4 below. Miombo Woodlands dominate the area immediately downstream of the Kafue Gorge. The figure further depicts the Kafue's vegetation cover, indicating the scattered distribution of woodlands on the Kafue River's levees and tributaries.

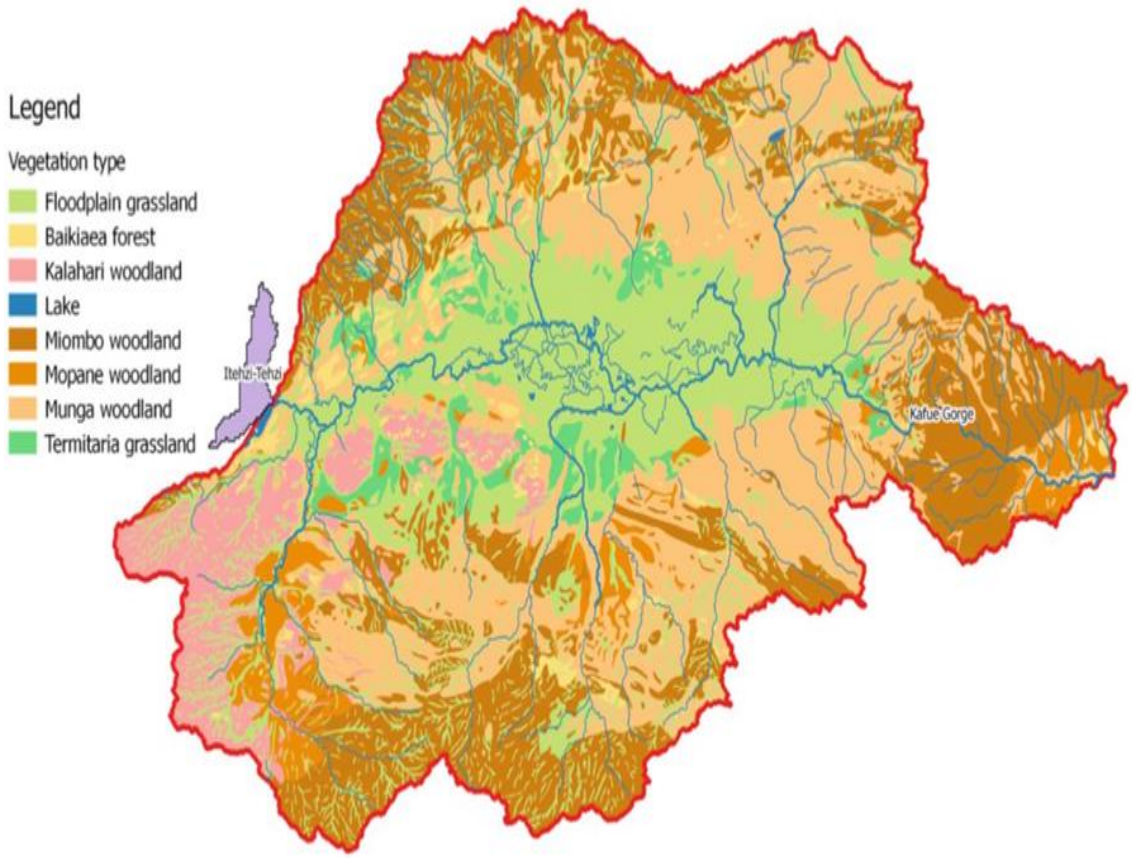


Figure 3- 4: Vegetation Map of the Kafue Basin

(Source: WWF Report, 2017)

3.4 Social Economic Activities

3.4.1 Population

Almost half of Zambia's entire population resides inside the Kafue basin, which is where the majority of the country's mining, industrial, and agricultural operations take place, contributing significantly to the country's economy (CSO,2010). The provinces of Northwestern, Copperbelt, Central, Lusaka, and Southern all receive water from the Kafue River. See Table 3-1 for a breakdown of provincial populations.

Table 3- 1: Population Density of Zambia by Province

Name	**Land Area (km^2)**	**2010 Population**	**2010 Population Density (Persons per km^2**
Zambia	752,612	13,092,666	17.4
Northwestern	125,826	727,044	5.8
Copperbelt	31,328	1,972,317	63.0
Central	94,394	1,307,111	13.8
Lusaka	21,896	2,191,225	100.1
Southern	85,283	1,589,926	18.6

Source: Central Statistics Office (2010)

Table 3-2 shows that around 59% of Zambia's total population lives in the Kafue basin. The Kafue flats were found to be the most prominent geographical feature in the Middle Kafue basin. There are just three provinces and seven districts in the basin, home to a total population of 5,088,262. according to the CSO 2010 Census.

Table 3- 2: Population density in the Kafue Basin

Name	**Land Area (km^2)**	**2010 Population**	**2010 Population Density (Persons per Square km**
Central Province	94,394	1, 307, 111	13.8
Itezhi Tezhi District	16, 064	68, 599	4.3
Mumbwa District	21, 103	226, 171	10.7
Lusaka Province	21, 896	2, 191, 225	100.1
Kafue(includes Chilanga & Shibuyunji Districts)	9, 396	227, 466	24.2
Southern Province	85, 283	1, 589, 926	18.6
Mazabuka,(includes Chikankata District	6, 242	230, 972	37.0
Monze District	4, 854	191, 872	39.5
Namwala District	5, 687	102, 866	18.1

Source: Central Statistics Office (2010)

3.4.2 Economic Activities

Cattle rearing and arable farming are crucial to the economy of the Middle Kafue Basin. One of Zambia's largest sugar cane plantations is in the Middle Kafue basin. Nakambala Sugar Estate, located near the city of Mazabuka, is Zambia's largest sugarcane growing facility (Nyambe, 2013). Private farmers, such as those affiliated with the Kaleya Smallholders Company, also contribute to the sugar cane harvest. It is common for people to fish in the basin along the river banks, as access to the Kafue flats is easy due to the flood plains. Herdsmen, whose success is quantified by the quantity of cattle they own, also make a living in the basin. In addition to its various economic interests, the Kafue basin is a major source of hydroelectric power from the Kafue gorge. Concentrations of various economic activity are depicted in Figure 3-5.

Figure 3- 5: Specific areas where different economic activities are concentrated (Source: WWF Brief,2016)

CHAPTER 4: METHODOLOGY

4.0 Introduction

Data for the study came from a variety of places and was gathered using a few distinct strategies, all of which are detailed in this section. This chapter describes the meteorological and hydrological data that is required to run the WEAP simulation model.

4.1 Research Focus

The study focused on application of WEAP Model to assess future water demands and effects of climate change in the Middle Kafue Basin. The basin is mostly devoted to commercial, subsistence, and livestock farming, as well as hydropower production, all of which are vital to the national economy and the regional economy of Southern Africa. Effective management of this Middle Kafue water demand is required to meet the region's many competing needs.

4.2 Data Collection

Both primary and secondary data were obtained. In order to examine the multisectoral uses of water in the basin, including water demand, questionnaires were utilized to collect primary data. In order to completely comprehend the Kafue Basin's inflows, the effort also required identifying the several important rivers of Kafue. The area was also surveyed with a drone to identify locations where crop irrigation was prevalent, and photographs of these areas were captured for use as primary data. This method was used to identify areas that were greener than others, indicating that these areas were being irrigated and visiting the actual locations confirmed whether these areas were being irrigated with borehole water or rain water. Secondary data consisted of obtaining records on the actual amounts of water utilized in the basin from water customers, the WARMA database, and other institutions involved in water resources management and development. It also entailed determining the sites of gauging stations used for discharge and flow measurements and collecting remotely sensed data for precipitation and temperature from Global Climate Databases and local sources.

4.3 Qualitative Data

The survey forms (Appendix 1) were used to analyse the multi-sectoral utilization of water resources in order to collect general data. This was done for the sectors that possessed water permits granted by Water Resources Management Authority, i.e. GPS location, the usage of water under their licences, and the abstraction points in order to comprehend the flow contribution to the main Kafue River from its tributaries.

During the inquiry, drone flights were arranged and the drone was flown across inaccessible locations to capture potential irrigation zones. The photographs underneath (Figure 4-1) depict the employed drone. In addition, the drone output photographs collected during field studies are as shown below (Figure 4-2 and 4-3).

Figure 4- 1: Drones used during the study

Figure 4- 2: Drone flight

Figure 4- 3: Image of drone flight showing Kafue River

Figure 4- 4: Gauging station at Munyeke River at Mapanza Mission

Gauging sites for flow monitoring in the Kafue Basin e.g. (Figure 4-4 above) were surveyed to determine their location and general condition. Physical inspections and discharge measurements in selected places were carried out, with the goal of relating the results to the actual rating curves that had been created from historical records. Some of the locations visited are shown below (Table 4-1 to 4-9).

Table 4- 1: Munyeke River at Mapanza Mission

Name of site	***Munyeke River at Mapanza Mission***
Latitude	-16.2477
Longitude	26.90574
Altitude	1018 metres above sea level

Table 4- 2: Kafue River at Namwala Pontoon

Name of site	***Kafue River at Namwala Pontoon***
Latitude	-15.671917
Longitude	26.450613
Altitude	1000 metres above sea level

Table 4- 3: Munyeke River at the Bridge

Name of site:	***Munyeke River at the Bridge***
Latitude	-16.520354
Longitude	26.5931940
Altitude	1023 metres above sea level

Table 4- 4: Bwengwe River

Name of site	***Bwengwa River***
Latitude	-16.09794
Longitude	27.11993
Altitude	998m above sea level

Table 4- 5: Chikumbwa River

Name of site	***Chikumbwa River***
Latitude	-16.1057
Longitude	27.23289
Altitude	1012 metres above sea level

Table 4- 6: Kaleya River

Name of site	***Kaleya River on the Great North Road***
Latitude	-15.90601
Longitude	27.67176
Altitude	991 metres above sea level

Table 4- 7: Magoye River

Name of site	***Magoye River at Chimbumbumbu***
Latitude	-15.96847
Longitude	27.60452
Altitude	1029 metres above sea level

Table 4- 8: Kaleya River near the source

Name of site	***Kaleya River near the source***
Latitude	-16.17546
Longitude	28.03119
Altitude	1254 metres above sea level

Table 4- 9: Kafue River at Kasaka

Name of site	***Kafue River at Kasaka***
Latitude	-15.82955
Longitude	28.21431
Altitude	972 metres above sea level

Figure 4- 6 Automated Stations: Kafue river at Namwala

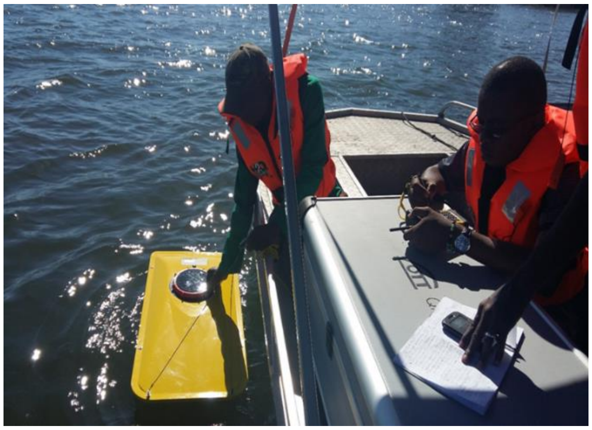


Figure 4- 5: Discharge measurements at Namwala

Actual measurements were conducted within the vicinity of the Kafue River at Namwala Pontoon (Figure 4-5) above and also discharge measurements were also gotten from automated gauging stations (Figure 4-6) shown above.

4.4 Quantitative Data

4.4.1 Modelling Process

For a more accurate simulation of runoff throughout the whole Kafue watershed, the Kafue basin was subdivided into 24 smaller basins. The flow gauges positioned within these sub basins served as excellent collection stations for runoff from precipitation, allowing for accurate simulation and model calibration across a wide section of the basin's tributaries. Figure 4-7 below depicts the Kafue Catchment's twenty-four sub basins. Only 16 of the 103 gauging sites in the Kafue basin were used to validate the model by comparing simulated and observed river flow (Figure 4-8). These 16 gauging stations were selected because of their convenient location along the Kafue River and the extensive data they collected over the years.

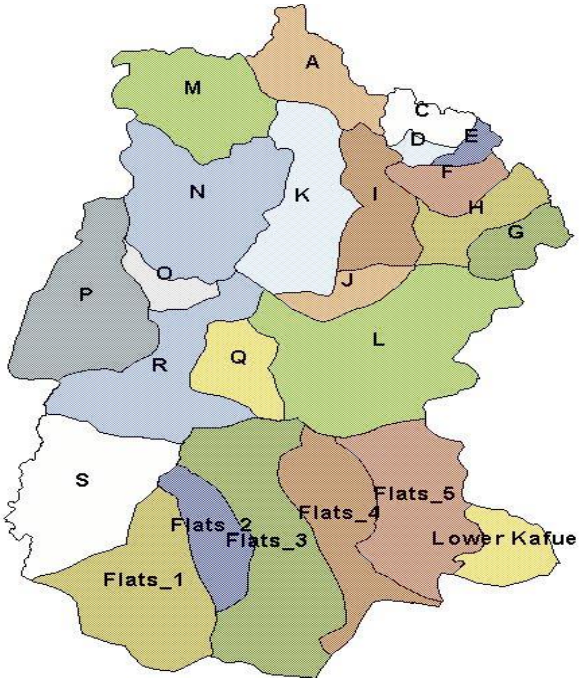


Figure 4- 7: Map Showing twenty-four Sub basins configured within Kafue Catchment

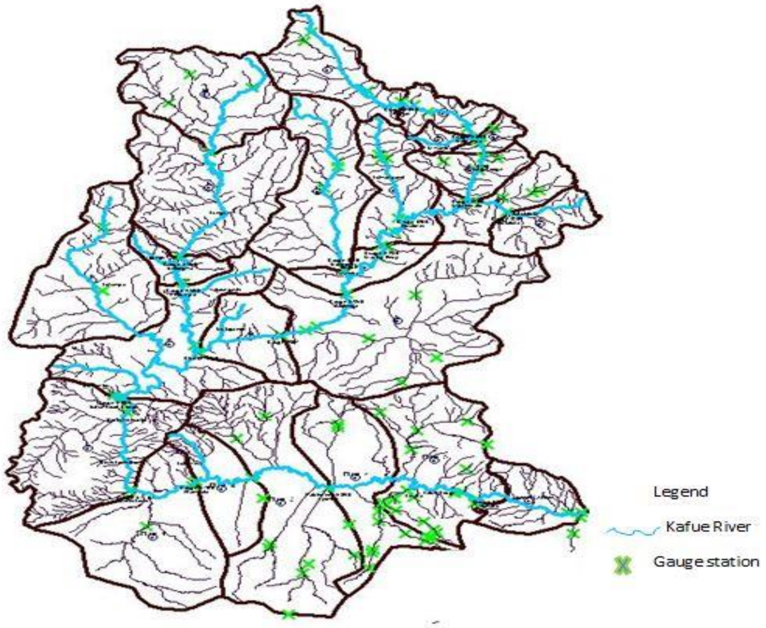


Figure 4- 8: Map Showing gauging stations within Kafue Basin

4.5 Data Analysis

4.5.1 Bias

Bias is defined as a concentration on or interests in one particular subject or a systematic distortion of a statistical result due to a factor not allowed for in its derivation. It can also be defined as a deviation of results from the truth or process leading to such deviation. Biasness was therefore avoided by applying standardized methods of analysis which was not limited to dealing with worst case and best cases scenarios equally. Biasness was also avoided by applying stratification of data gathered which is a process of separating the collected samples into several sub-samples.

4.5.2 Simulation of the Natural Flows

Water Resources Management Authority (WARMA) streamflow data and climate (evaporation, rainfall, and temperature) data from 1957 to 2012 were employed in the model. Components of the Kafue basin data, such as surface water supply sources, water use were also collected (i.e. Agricultural and industrial). The Kafue basin map was among the gathered GIS spatial data used to pinpoint the specific locations of the various demand nodes. There are multiple users of water in the Kafue Basin, and their locations were verified as shown in Figure 4-9.

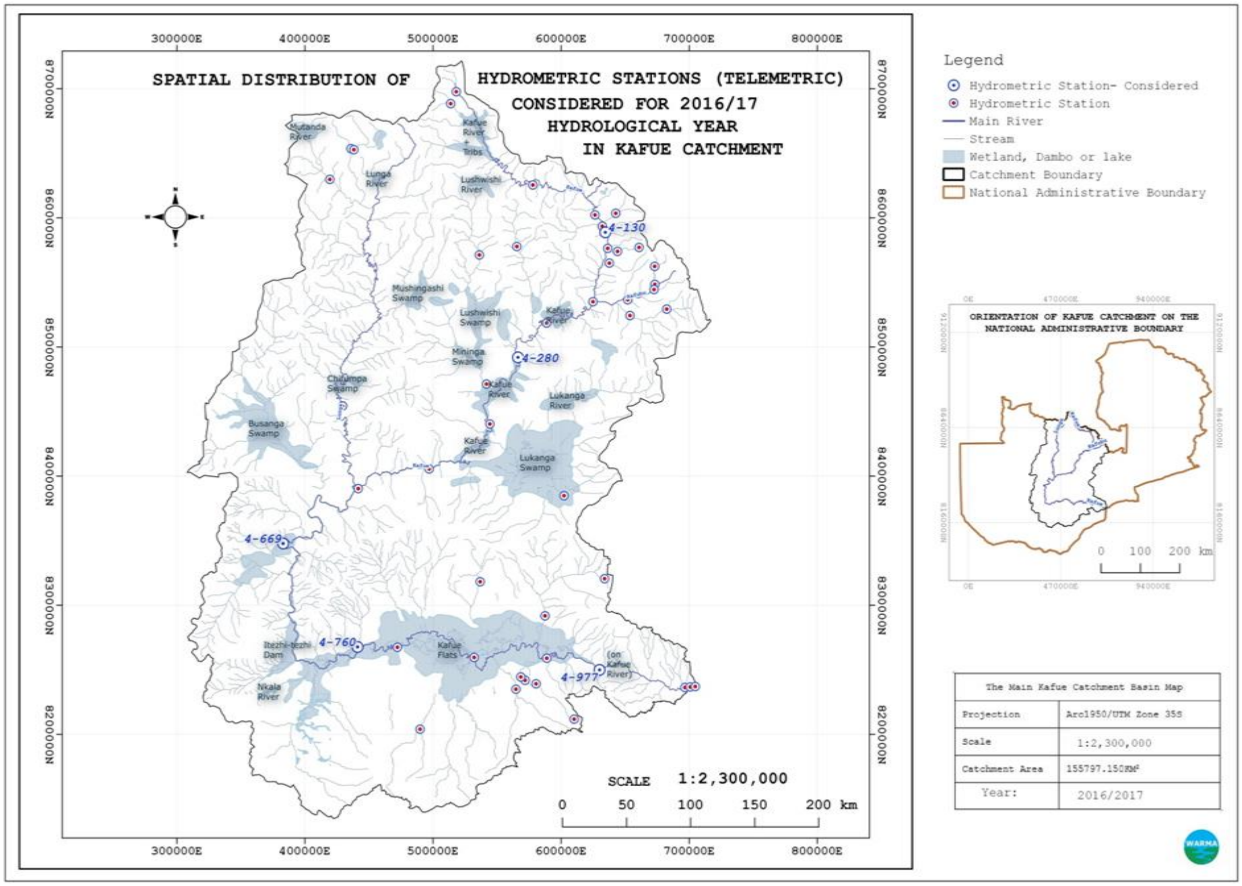


Figure 4- 9: Validated locations of the different water users within the Kafue Basin (Source: WARMA, 2018)

After these variables were entered into the model, simulations of natural hydrological processes were performed to evaluate the water supply in the Kafue Basin, and simulations of anthropogenic activities including anthropogenic climate change activities were superimposed on the natural system to determine their impact on water availability and distribution. To run the model, the Kafue River was split up into segments called "reaches" (Figure 4-10), with the limits of each reach marking the distance from one abstraction or return flow to another, as well as the locations of any dams or gauging stations in the Kafue basin. The model then accounted for abstractions and inflows before running a mass balance of flow from the northern to southern end of the Kafue basin. As such, the WEAP model was set up to simulate a baseline (recent) year, for which the water supply and demand was calculated, before simulating various climate change scenarios. To solve problems with sectoral demand studies, water conservation, water licenses and allocation priorities, and streamflow simulation, the WEAP model was implemented in both industrial and agricultural settings.

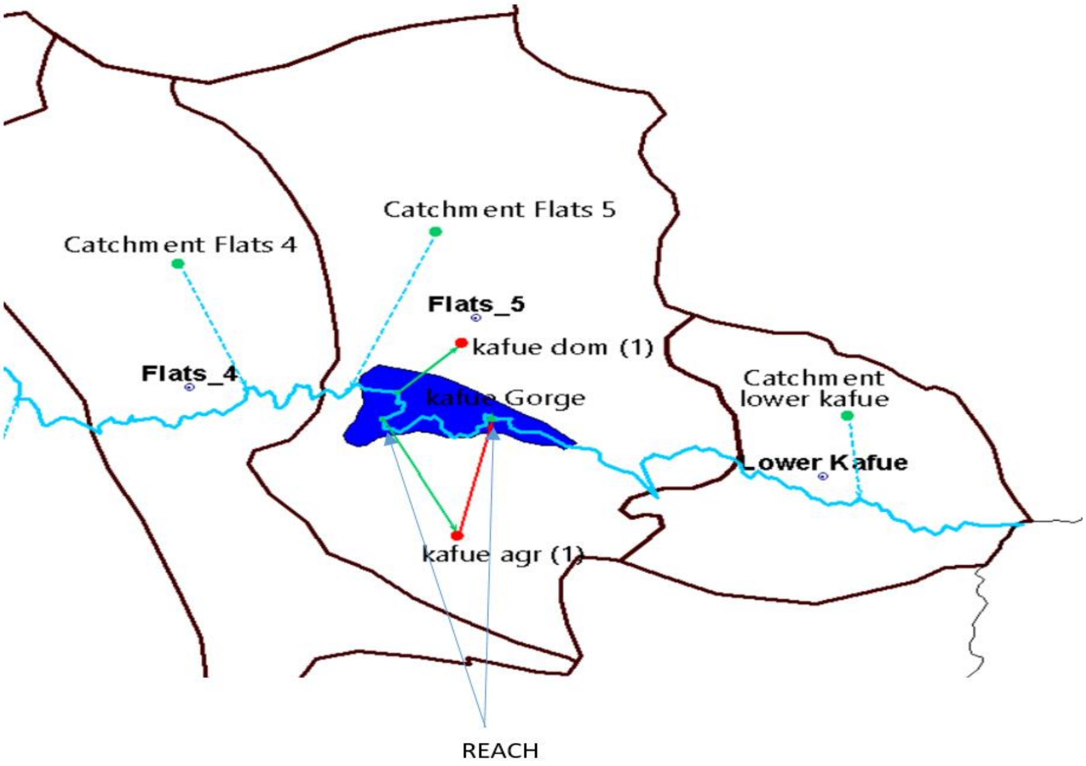


Figure 4- 10: Definition of the ‘’REACH’’

4.5.3 Climate Projections in WEAP

The study employed climatic data from the Swedish Meteorological and Hydrological Institute (SMHI) and from Coordinated Regional Climate Downscaling Experiment (CORDEX) for both historical and future data to evaluate the effects of climate change.

The General Circulation Models (GCM) data used was an atmospheric general circulation model which was developed by Max Planck Institute for Meteorology in Hamburg, Germany (ECHAM) downscaled to 0.44 degrees (approximately 50 km) resolution. World Climate Research Programme's CORDEX program aims to create a framework for evaluating regional climate downscaling methodologies using global climate estimates that have been downscaled (Ozturk et al, 2012). Representative Concentration Pathways (RCPs) are used in CORDEX's emission scenarios. International Panel on Climate Change (IPCC) adopted these RCPs for its Fifth Assessment report in 2014 to depict future emission paths and greenhouse gas concentrations in the year 2100 (Wayne, 2013). There are four potential RCPs, each representing a different level of radiative forcing by the year 2100 (RCP8.5, RCP6, RCP4.5, and RCP2.6). The scenarios considered for this analysis included the period from 1900 to 2100. Furthermore, the WEAP model only considered the two scenarios (RCP4.5 and RCP8.5) and the single reference scenario.

CHAPTER 5: RESULTS

5.0 Introduction

This chapter summarizes the outcomes of the research from the analysis that took place after the model was constructed and data was entered in order to simulate the three distinct scenarios that were evaluated throughout the course of the investigation. This chapter shows comparisons between simulated and observed flows and discusses the effects of climate change on the Kafue Basin. Observed flows are compared to simulated flows. In addition to this, it discusses the various uses of water across multiple industries in the Kafue basin.

5.1 Modelling water allocation using WEAP

5.1.1 Water Availability in the Kafue Basin

Only 16 gauging stations in the Kafue basin were found to be suitable for validation and subsequent model calibration. Some of the stations with gaps in their historical data also underwent flow discharge measurements to check their accuracy. Some typical gauge readings (Table 5-1) were tabulated together with discharge measurements (Table 5-2).

Table 5- 1: Gauge readings within the Kafue Basin

1	**Name of site**	**Munyeke River at Mapanza Mission**
	Gauge plate reading	0.43 metres
	Estimated Width	12 metres
2	Name of site	Kafue River at Namwala Pontoon
	Gauge reading	0.666 metres
	Estimated Width	200 metres

3	Name of site	Kafue River at Namwala Pontoon
	Gauge reading	0.666 metres
	Estimated Width	200 metres
4	Name of site	Munyeke River at the Bridge above sea level
	Gauge reading	0.5 metres
	Estimated Width	6 metres
5	Name of site	Bwengwa River
	Gauge reading	0.35 metres
	Estimated Width	6 metres
6	Name of site	Kaleya River on the Great North Road
	Gauge reading	0.12 metres
	Estimated Width	1.25 metres
6	Name of site	Magoye River at Chimbumbumbu
	Gauge reading	0.253 metres
	Estimated Width	0.85 metres
7	Name of site	Kaleya River at near source
	Gauge reading	0.532 metres
	Estimated Width	4 metres
8	Name of site	Kafue River at Kasaka
	Gauge reading	8.59 metres
	Estimated Width	230 metres

Table 5- 2: Discharge readings within the Kafue Basin

Gauge No.	River/Station	Discharge (m^3/s)
4-710	Kafue ITT	698.280
4669	Kafue/Hook Bridge	832.833
4450	Kafue/Lubungu,	511.936
4560	Lunga/Chifumpa	196.730
4620	Lufupa/Kasempa	6.822
4302	Luswishi/Lwendo	42.514
4340	Lushishi/Kangondi	60.175
4821	Munyeke/Mapanza	3.014
4760	Kafue/Nanwala Pontoon,	569.492
Misc.	Munyeke/ Monze-Niko Road	3.511
Misc.	Bwengwa/ Monze-Niko Road	2.994
Misc.	Nakasangwe/ Monze-Niko Road	1.354
4890	Kafue/Nyimba	390.750
4915	Magoye/Chimbumbu,	1.807
4949	Kaleya/G.N.R	0.195
4977	Kafue/ Chiawa Bridge	155.687
4977	Kafue/Kasaka	445.801

Hydro-meteorological stations data, evaporation rates, and input and return flow rates to the Kafue basin from its tributaries were all considered for the evaluations. Only 22 of the total 65 stations in the Kafue basin are Telemetric Stations, which means that their data is transmitted from the station to the location where it is monitored and analysed. The Itezhi-tezhi Dam, run by ZESCO Power Company, receives an average inflow of $301m^3/s$ from the Middle Kafue basin, located about 270 km from the Kafue Gorge lower. Approximately 27 million m^3 of water is recycled each year in the Kafue basin's central region. Based on estimates of water use in cities, factories, mines, and farms, return flows are calculated (Chomba, M.J., and Nkhata, B.A., 2016). Evaporation in the middle Kafue basin is estimated to be between 1,605 and 2,166 millimetres per year, compared to the national average of 2,061 millimetres. It was calculated that 289 m^3/s was the average rate of water flowing into Kafue Gorge Dam (KGD).

5.1.2 WEAP Modelling

A simulation of the WEAP model was conducted by feeding data on the Kafue basin's influx into it. The modelled Kafue basin and its major tributaries are shown below (Figure 5-1)

Figure 5- 1: Kafue River inflow map

The acquired data from CORDEX, which included mean precipitation and temperature values were then entered into the model to run under the natural flow conditions to show the simulated flows. When analysing linear regressions for empirical model evaluation, the observed value is plotted on the Y axis and the predicted value is plotted on the X axis

(Pineiro, 2008). Plotting the values in reverse would result in inaccurate and incorrect estimates of the slope and Y-intercept, leading to false results when testing for correlation. The output of CORDEX's annual precipitation sum compared to observed flows is shown below (Figure 5-2).

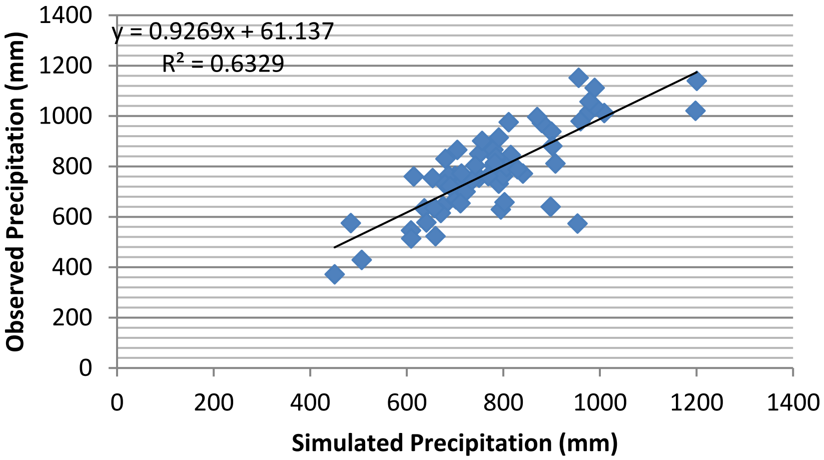


Figure 5- 2: Sum of yearly precipitation between simulated and observed values

5.1.2.1 Climate Scenario

The Representative Concentration Pathway 4.5 (RCP4.5) is a stabilization scenario that assumes a level of radiative forcing of 4.5 W/m^2 before the year 2100, with emissions mitigated by a variety of techniques for lowering greenhouse gas emissions.

The Radiative Forcing Scenario (RCP 8.5) is the greatest emission scenario for greenhouse gases that does not account for any specific climate mitigation initiatives.

In this context, "reference scenario" is the scenario derived from the period's Current Accounts (baseline) data, in which "business as usual" is assumed (1900 to 2100)

For the years 1951 through 2100, the eight climate models published by SMHI provide annual means for both RCP 4.5 (Appendix 3) and RCP 8.5 (Appendix 4).

To determine which temperature-climate models to include in the WEAP simulation model, statistical analyses was performed on all eight models. Developed graphs for each climate model are displayed (Figure 5-3 to 5-10).

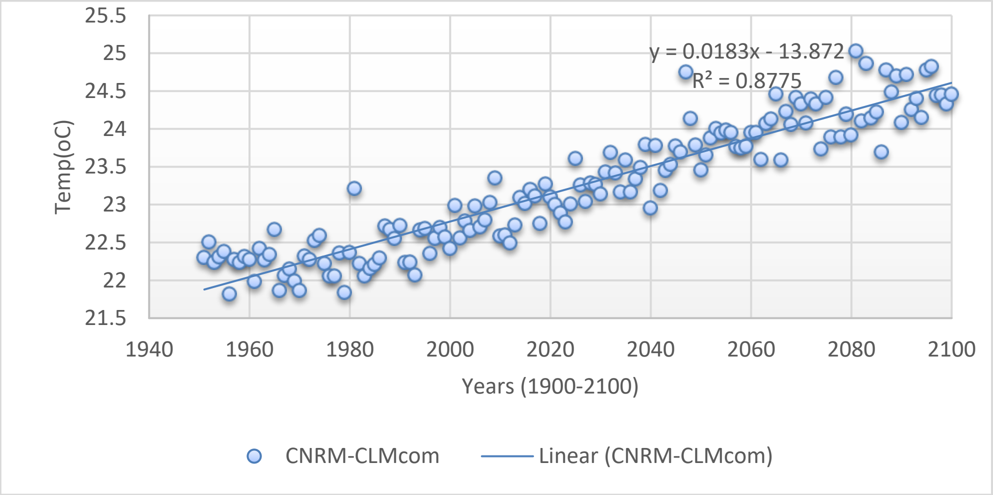


Figure 5- 3: CNRM-CLMcom- Climate Model for the projected temperatures between the years 1900 to 2100

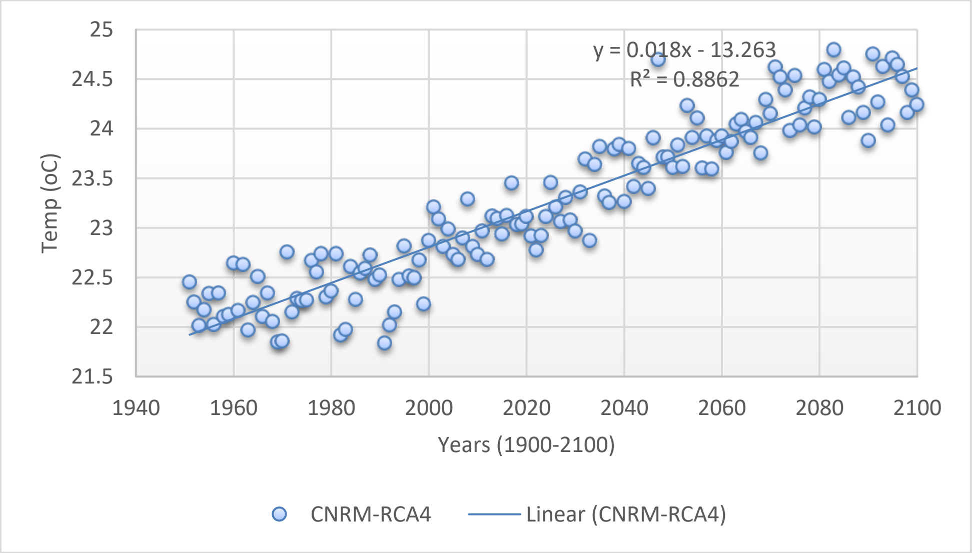


Figure 5- 4: CNRM-RCA4- Climate Model for the projected temperatures between the years 1900 to 2100

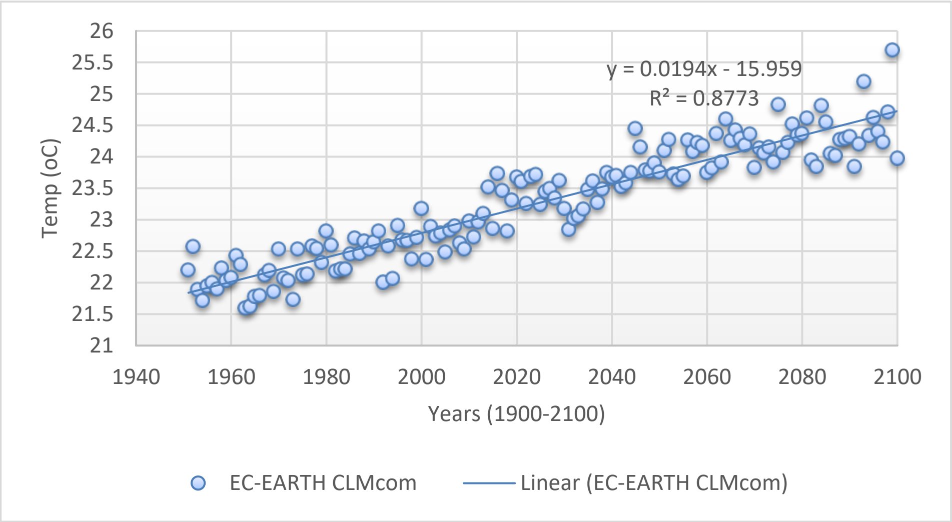


Figure 5- 5: EC-EARTH – Climate Model for the projected temperatures between the years 1900 to 2100

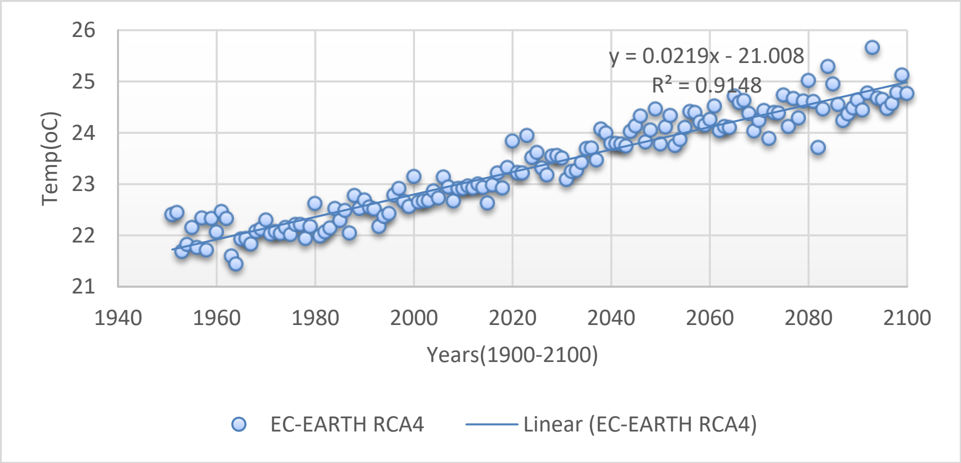


Figure 5- 6: EC-EARTH RCA4-Climate Model for the projected temperatures between the years 1900 to 2100

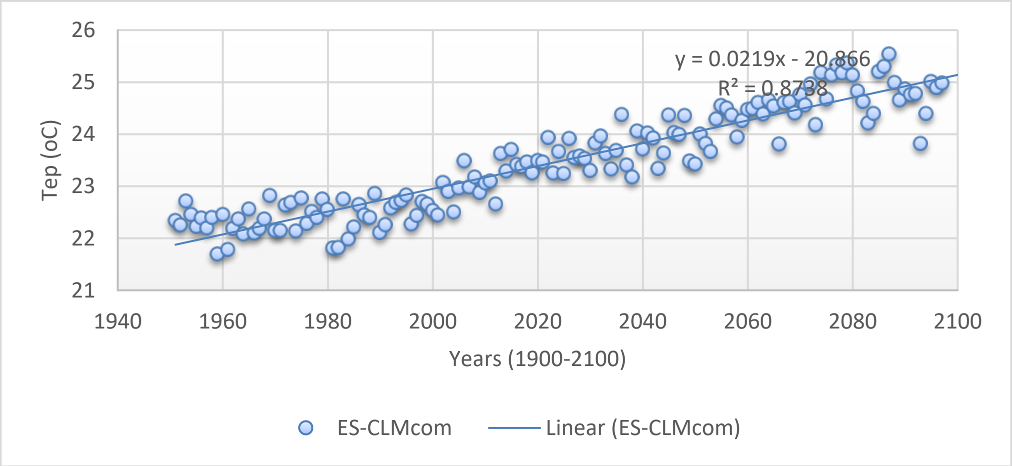


Figure 5- 7: CLMcom-Climate Model for the projected temperatures between the years 1900 to 2100

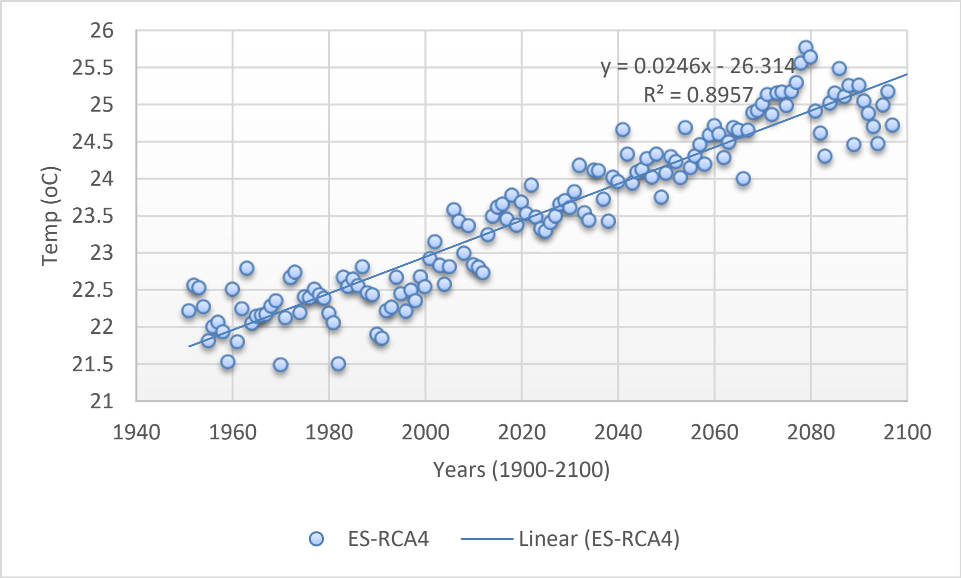


Figure 5- 8: RCA4-Climate Model for the projected temperatures between the years 1900 to 2100

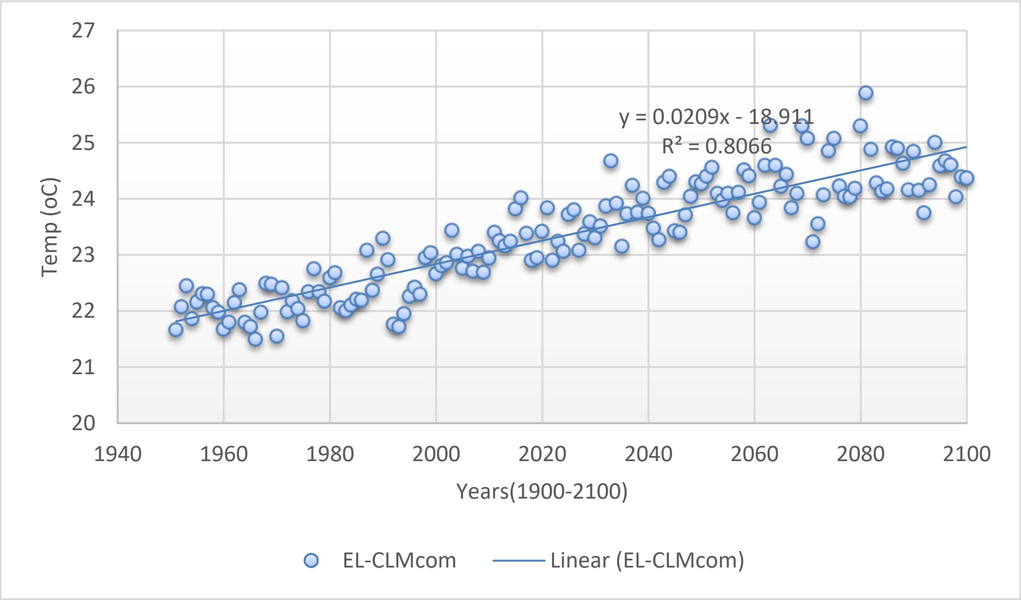


Figure 5- 9: CLMcom-Climate Model for the projected temperatures between the years 1900 to 2100

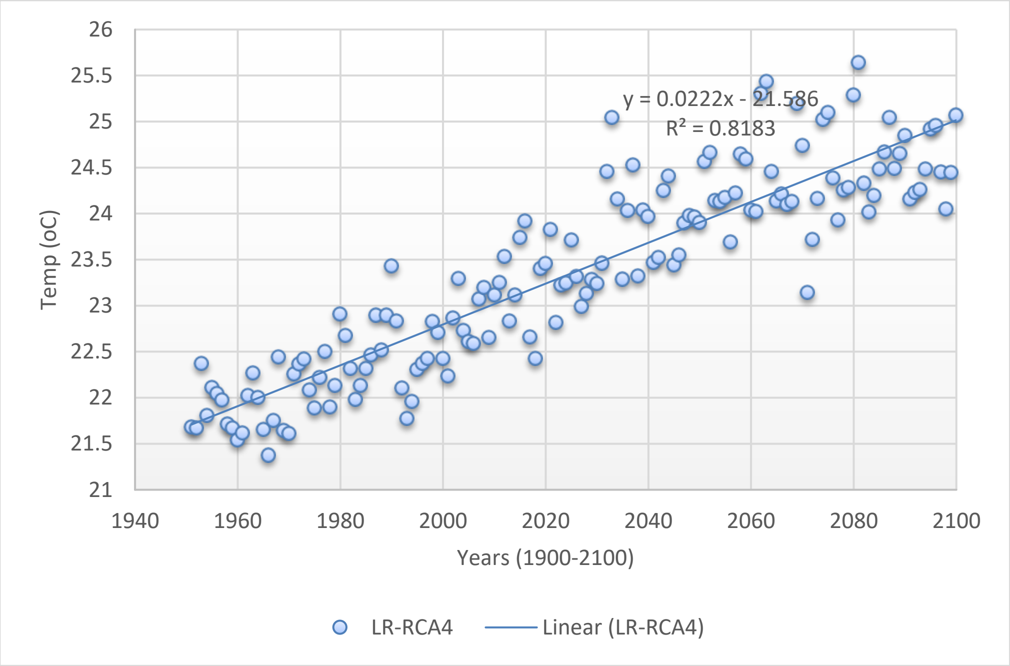


Figure 5- 10: LR-RCA4- Climate Model for the projected temperatures between the years 1900 to 2100

In order to determine the runoff pattern in the Kafue basin, SHMI's precipitation data for the same time period (1951 to 2100) was also inserted into the WEAP model.

5.1.3 WEAP Model

The data sets which were developed from GIS software were imported into the WEAP model. These datasets included both vector (shape files and feature classes) and raster (Grids) files for gauge stations and hydrological basins respectively. Figure 5-11 shows the Kafue basin that was modelled using WEAP.

Figure 5- 11: Modelled Kafue Basin

The inflows and out flows into the middle Kafue basin were modelled to indicate the flows into the basin and the outflows of the middle Kafue basin respectively. The inflow (Figure 5-12) was observed from the first sub-basin of the Middle Kafue Basin I.e. Catchment Flat 1, and the outflow was observed at the outlet i.e. Lower Kafue Catchment of the Middle Kafue basin thus the WEAP model was able to simulate flows in and out of the basin.

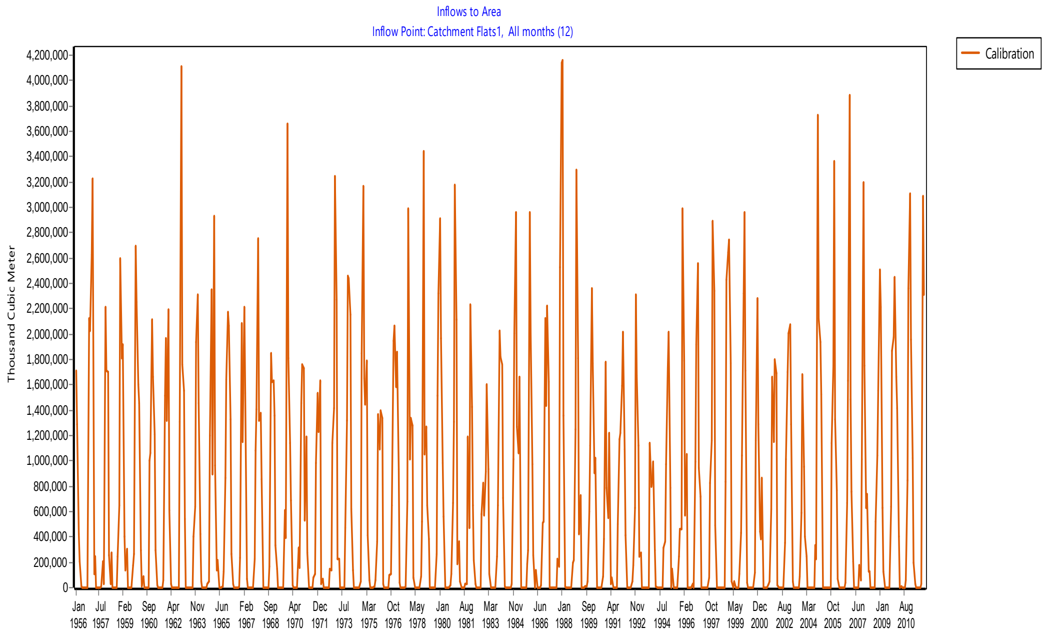


Figure 5- 12: Inflow into the ‘’Catchment Flat 1’’ of the Middle Kafue Basin

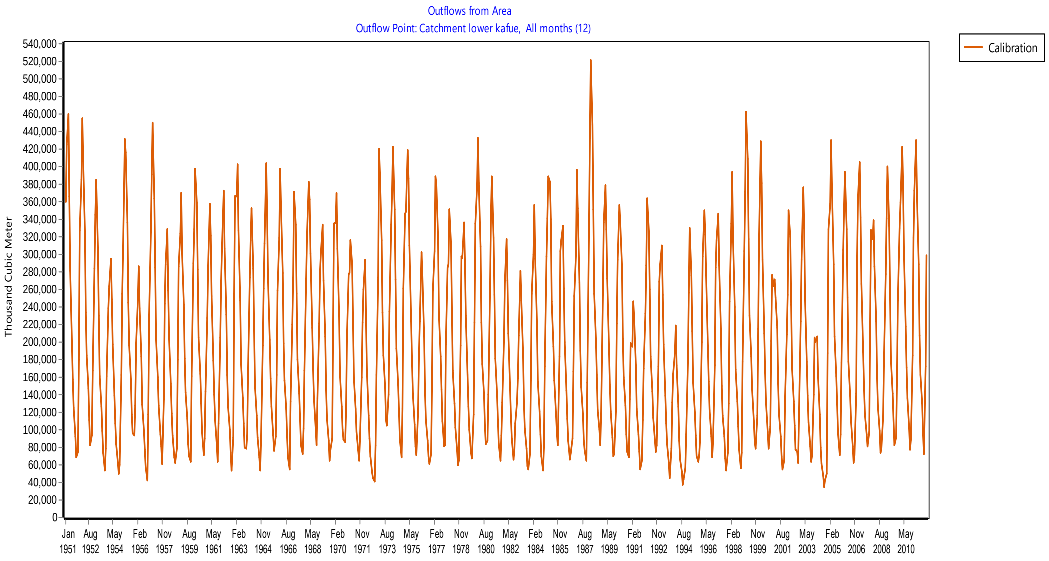


Figure 5- 13: Outflows below the ‘’ Lower Kafue’’ of the Middle Kafue Basin

From the inflows and outflows above, the percentage change in the flow was calculated as shown below.

Percentage change = $\frac{(Inflows-Outflows)}{Inflow} * 100$

The percentage change in flows was found to 24.6%. The percentage in flow was attributed to evaporation and demand points which were entered in the model. This shows that the model was able to simulate the flows hence capable of being used in river flow simulations.

5.2 Water Demand

5.2.1 Multi-sectoral Uses of Water

Over 96.9% of consumptive users in the Kafue basin are in agriculture, making this resource extremely important for social and economic growth. Drone footage also revealed some hidden irrigation activities that WARMA had no record of (Figure 5-14). As a result of the poor terrain conditions, some of these locations were off limits during the field visits (Figure 5-15).

Figure 5- 14: Drone image captured near Itezhi – tezhi Dam

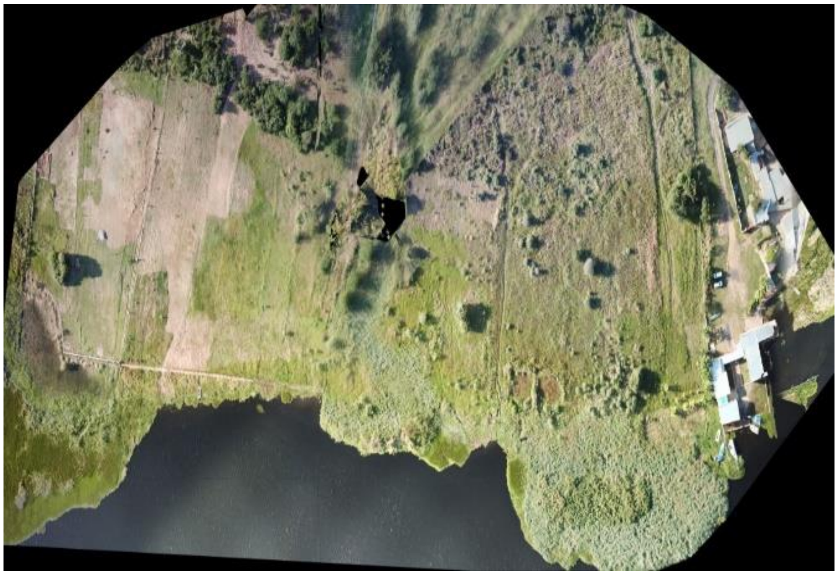


Figure 5- 15: Drone image captured near Kafue Bridge

Some of the Kafue basin's biggest water users also come from the industrial, recreational, and hydropower sectors, as can be seen in Figure 5-16 below. Water allocation for hydro-power generation now stands at 301m^3/s, with the majority of the water going to the large hydropower plants at Itezhi-Tezhi (ITT) and Kafue Gorge Dam (KGD). The majority of agricultural water resources are put toward sugar cane irrigation. To meet the needs of the city's residents, the Lusaka Water and Sewerage Company draws groundwater which is then pumped to storage for the purposes of supplying those connected to their supply lines. Table 5-3 below shows that 1.17 percent of the catchment's water is used for non-consumptive hydropower and 1.93 percent is used by water utility companies.

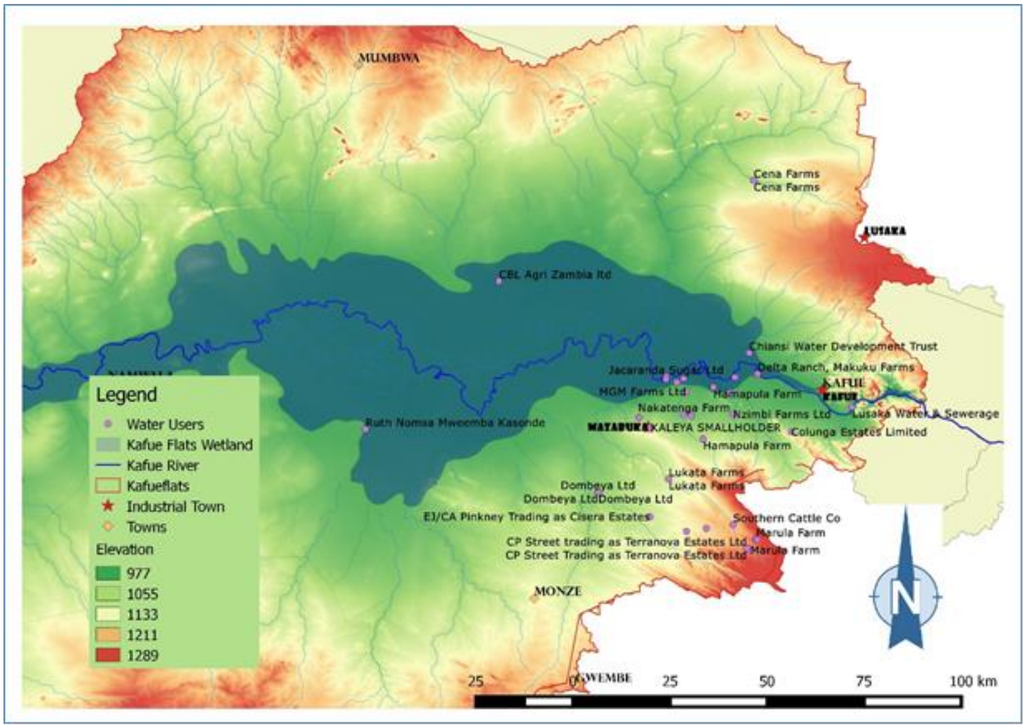


Figure 5- 16: Major Commercial users within the Kafue Basin

Table 5- 3: Different categories of water uses in the Kafue Basin

CATEGORY	**M^3/DAY**
IRRIGATION	2,819,401
HYDROPOWER	41,040,000
WATER SUPPLY	175,500
LIVESTOCK/COMMUNITY USE	126,000
TOTAL	44,286,901

7.2.1 Environmental Requirements for Kafue River Basin and Climate variability

When there are several users and conflicting demands for a river's water, the term "environmental flows" is used to describe how the river's water is managed to preserve the ecosystem and its benefits. The only section of the Kafue basin where environmental flows have been assigned in the past is the section downstream of Itezhi Tezhi Dam, equivalent to $25m^3/s$ (Kalumba and Nyirenda, 2017). Precipitation averages over 1,300 mm in the northern half of the country and around 800 mm in the southern half. Mean monthly temperatures range from 14°C to 27°C in June and July, respectively; mean maximum and minimum temperatures range from 16°C to 34°C in October and 7°C to 24°C in July; and rainfall is relatively abundant throughout the year.

7.3 Climate Models

Since there is no enough data on the effects of climate change to make an accurate assessment of Africa's susceptibility to its effects, efforts have been made to narrow the range of possible projections by focusing on the most extreme ones (Muller, 2009), limiting the number of climate models used to just three i.e. Regional Climate Models (RCM), Climate Limited-area Modelling-Community (CLMcom), and the Rossby Centre Regional Atmospheric Model (RCA4). All these three were driven by four Global Climate Models which were among the eight climate models from the Coordinated Regional Climate Downscaling Experiment for Africa - (CORDEX-AFRICA) that were examined (GCM). The Met Office Hadley Centre (Hadley Centre Global Environment Model version 2) coupled Earth System model (MOHC-HadGEM2-ES), the Irish Centre for High End Computing, the European Commission, the Met Office Hadley Centre (Hadley Centre

Global Environment Model version 5), the Max Planck Institute for Meteorology, and the European Commission (MPI-M-MPI-ESM-LR). Swedish Metrological and Hydrological Institute provided both the CORDEX-Africa temperature and precipitation records (SMHI). Below (Table 5-4) is a condensed format for the combination of GCMs and RCMs utilized in the study, and the data included Representative Concentration Pathways 4.5 and 8.5 (RCP4.5 and RCP8.5).

Table 5- 4: Short format used for the Combination of GCM'S and RCM's

GCM	***RCM***	***Abbreviation used in this study***
MPI-M-MPI-ESM-LR	RCA4	LR_RCA4
MOHC-HadGEM2-ES	RCA4	ES_RCA4
CNRM-CERFACS-CNRM-CM5	CLMcom	CM5_CLMcom
ICHEC-EC-Earth	CLMcom	Earth_CLMcom
MOHC-HadGEM2-ES	CLMcom	ES_CLMcom
CNRM-CERFACS-CNRM-CM5	RCA4	CM5_RCA4
ICHEC-EC-Earth	RCA4	Earth_RCA4
MOHC-HadGEM2-EL	CLMcom	EL_CLMcom

Assuming that extreme conditions had to be implemented in order to manage water resources successfully via model tools, statistical analysis was performed on the temperature data from all eight models, and only those that demonstrated both extremes and medium conditions were chosen. Tables 5-5, 5-6 and 5-7 display the statistical results obtained from the three climate models utilized in the study. Table 5-8 shows regional climate scenarios.

Table 5- 5: CNRM-RCA4 Statistical Analysis

Statistic	**CNRM-RCA4**
Nbr. of observations	150
Minimum	21.838
Maximum	24.795
Freq. of minimum	1
Freq. of maximum	1
1st Quartile	22.563
Median	23.165
3rd Quartile	23.960
Mean	23.266
Variance (n)	0.688
Variance (n-1)	0.693
Standard deviation (n)	0.830
Standard deviation (n-1)	0.832
Lower bound on mean (95%)	23.131
Upper bound on mean (95%)	23.400

Table 5- 6: EC-EARTH CLMcom Analysis

Statistic	**EC-EARTH CLMcom**
Nbr. of observations	150
Minimum	21.593
Maximum	25.696
Freq. of minimum	1
Freq. of maximum	1
1st Quartile	22.538
Median	23.393
3rd Quartile	24.057
Mean	23.283
Variance (n)	0.802
Variance (n-1)	0.808
Standard deviation (n)	0.896
Standard deviation (n-1)	0.899
Lower bound on mean (95%)	23.138
Upper bound on mean (95%)	23.428

Table 5- 7: ES CLMcom Analysis

Statistic	**ES-CLMcom**
Nbr. of observations	150
Minimum	21.690
Maximum	25.535
Freq. of minimum	1
Freq. of maximum	1
1st Quartile	22.568
Median	23.459
3rd Quartile	24.372
Mean	23.476
Variance (n)	0.989
Variance (n-1)	0.996
Standard deviation (n)	0.995
Standard deviation (n-1)	0.998
Lower bound on mean (95%)	23.313
Upper bound on mean (95%)	23.638

Table 5- 8: Regional Climate Scenarios: Precipitation Information

Source: SMHI, (2016)

Climate Variables	Precipitation (mm/day)
Spatial resolution	0.44 degree (approx. 50 km at the equator)
Temporal resolution	Daily
Time period	1951-01-01 – 2050-12-31

5.3.1 Climate Model Analysis

Representative Concentration Pathway projections were used to simulate the inflow at the Itezhi Tezhi dam (ITTD), with three of the eight climate models chosen under two different projections, RCP 8.5 and RCP 4.5. The results for the model are shown below in Figures 5-17 to 5-22 below;

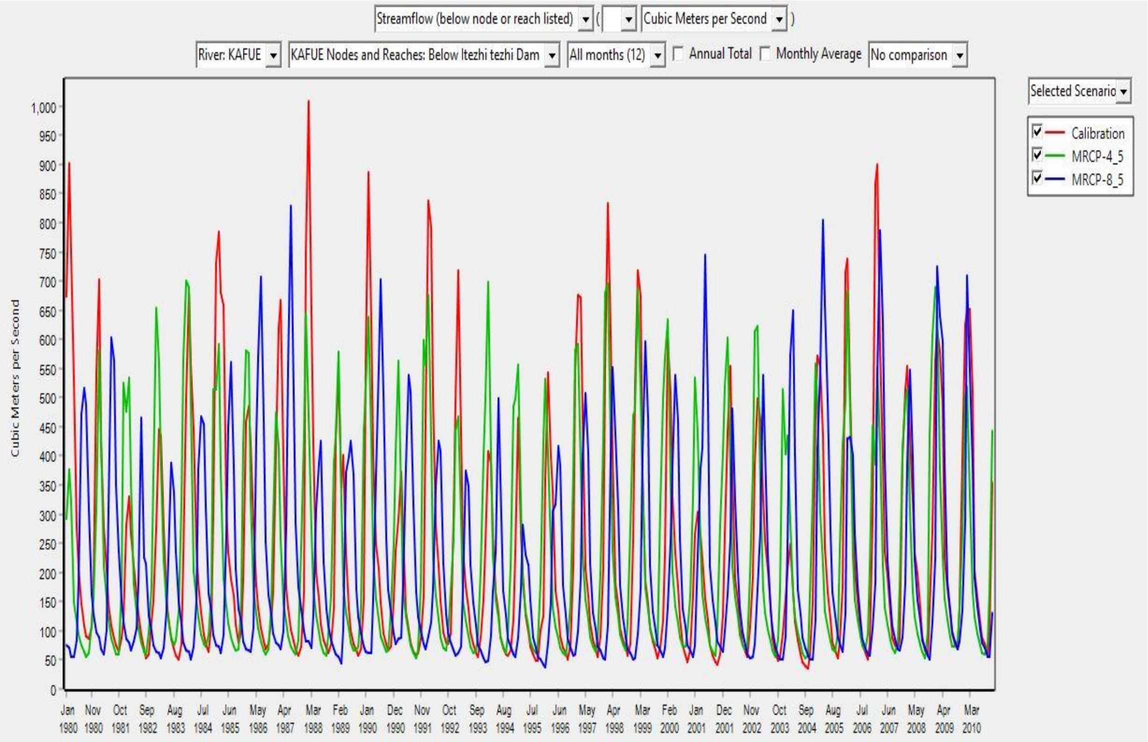

Streamflow (below node or reach listed) ( ) Cubic Meters per Second)
River: KAFUE | KAFUE Nodes and Reaches: Below Itezhi tezhi Dam | All months (12) | ☐ Annual Total | ☐ Monthly Average | No comparison
Selected Scenario
☑ Calibration
☑ MRCP-4_5
☑ MRCP-8_5

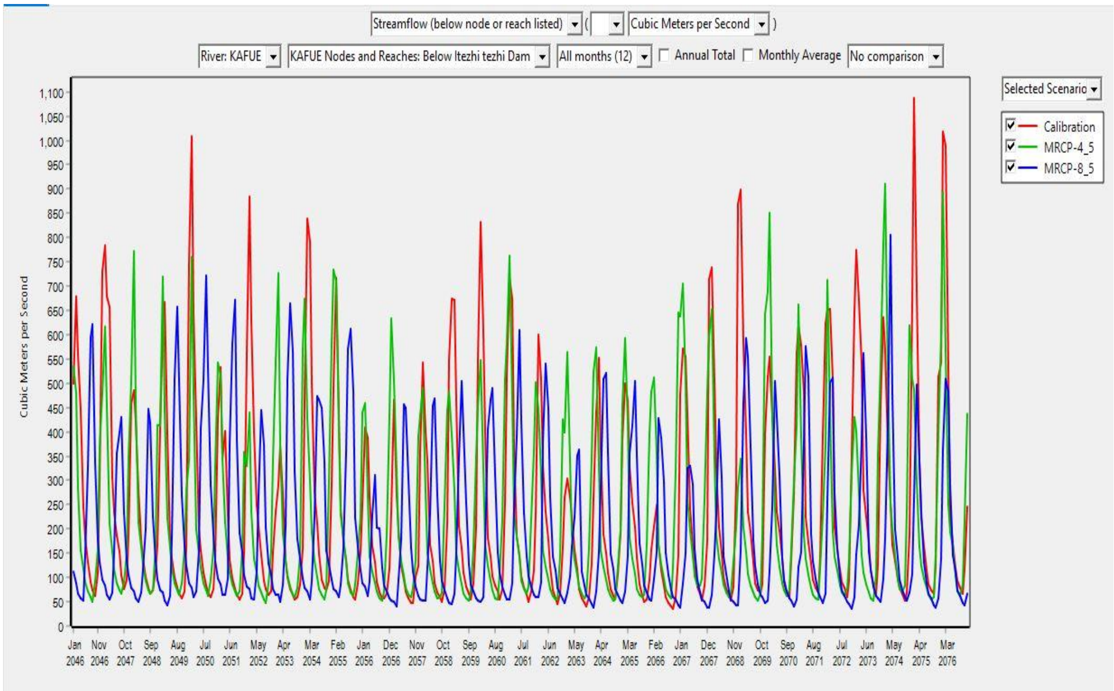
Figure 5- 17: Simulation of Inflow at Itezhi – tezhi Dam

Under RCP 4.5, the simulated climate model in WEAP shows a decrease in flows between the years 1980 and 2010 and between the years 2046 and 2076, compared to the reference period. For both the 1980–2010 and the 2046–2076 time periods, RCP 8.5 was the same as the baseline.

The margin of error in the precipitation data was calculated to be 5.970.6 approximately 6.0, as shown below (Table 5-9).

Table 5- 9: Confidence Interval – Precipitation (mm)

Sample Siz	***Average***	***Standard Devaition***	***Margin of error***	***Max***	***Min***
1760	100.85	127.9	6.0	490	0



Streamflow (below node or reach listed) ( ) Cubic Meters per Second)

River: KAFUE KAFUE Nodes and Reaches: Below Itezhi tezhi Dam All months (12) ☐ Annual Total ☐ Monthly Average No comparison

Selected Scenario

Figure 5- 18: Modelled Stream flow between the years 2046 to 2076

Streamflow (below node or reach listed) ▾ (▾ Cubic Meters per Second ▾)

River: KAFUE ▾ KAFUE Nodes and Reaches: Below Itezhi tezhi Dam ▾ All months (12) ▾ ☐ Annual Total ☐ Monthly Average Relative to Calibration ▾

Selected Scenario ▾

☑ Calibration
☑ MRCP-4_5
☐ MRCP-8_5

Figure 5- 19: MRCP -4.5 Relative flows to baseline flows (1980 -2010)

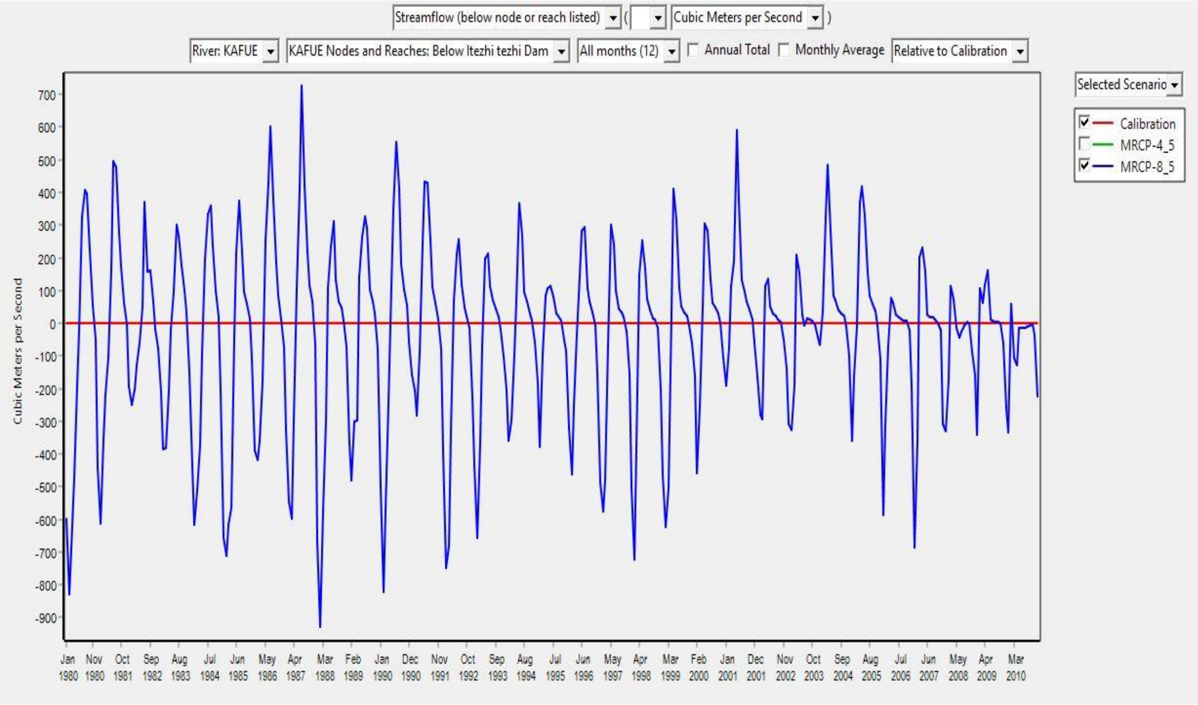
Streamflow (below node or reach listed) ▾ (▾ Cubic Meters per Second ▾)

River: KAFUE ▾ KAFUE Nodes and Reaches: Below Itezhi tezhi Dam ▾ All months (12) ▾ ☐ Annual Total ☐ Monthly Average Relative to Calibration ▾

Selected Scenario ▾

☑ Calibration
☑ MRCP-4_5
☐ MRCP-8_5

Figure 5- 20: MRCP-4.5 Relative flows to baseline flows (2046-2076)



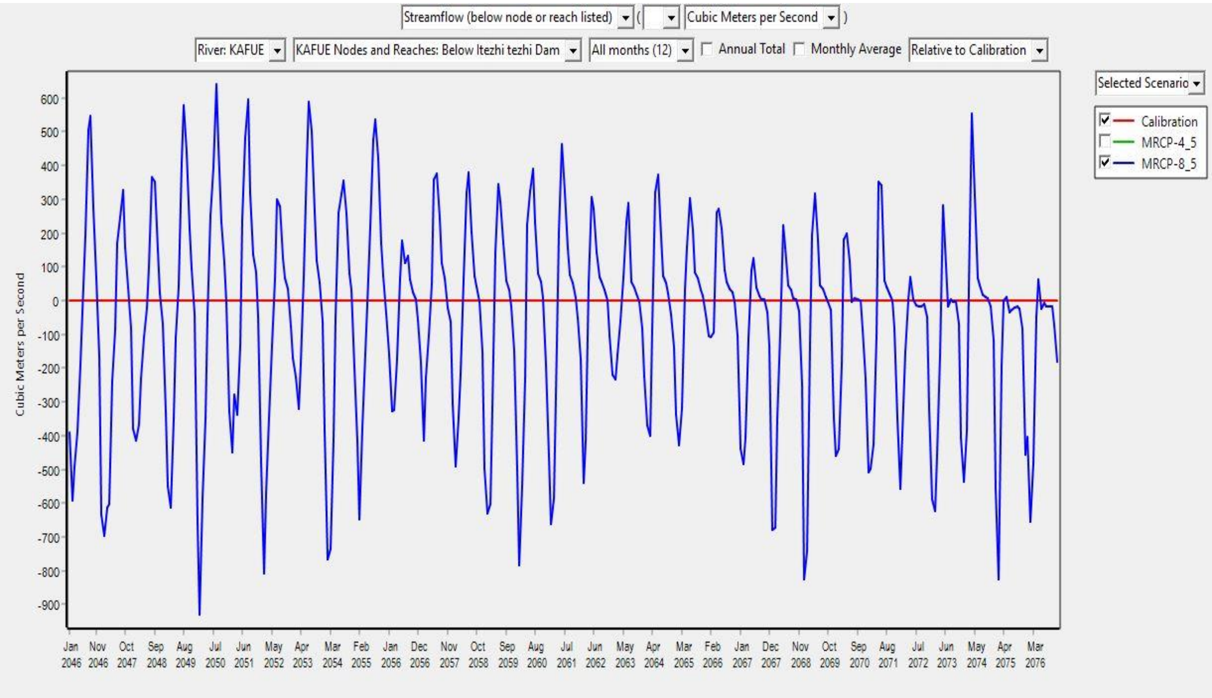
Streamflow (below node or reach listed) ▾ (▾ Cubic Meters per Second ▾)

River: KAFUE ▾ KAFUE Nodes and Reaches: Below Itezhi tezhi Dam ▾ All months (12) ▾ ☐ Annual Total ☐ Monthly Average Relative to Calibration ▾

Selected Scenario ▾

☑ Calibration
☐ MRCP-4_5
☑ MRCP-8_5

Figure 5- 21: RCP-8.5 Relative flows to baseline flows (1980 – 2010)



Streamflow (below node or reach listed) ▾ (▾ Cubic Meters per Second ▾)

River: KAFUE ▾ KAFUE Nodes and Reaches: Below Itezhi tezhi Dam ▾ All months (12) ▾ ☐ Annual Total ☐ Monthly Average Relative to Calibration ▾

Selected Scenario ▾

☑ Calibration
☐ MRCP-4_5
☑ MRCP-8_5

Figure 5- 22: RCP -8.5 Relative flows to baseline flows (2046 -2076)

The percentage change in flow under RCP – 8.5 and RCP – 4.5 in the period 1980 – 2010 showed the following results (Table 5-10).

Table 5- 10: Percentage Change (1980 – 2010)

Period	***1980-2010***
Reference	**242**
MRCP 4_5	**233**
MRCP 8_5	**208.5**
%CHANGE 4.5	**3.7**
%CHANGE 8.5	**13.8**

According to the findings, the projections made using RCP – 8.5 for the time period between 1980 and 2010 revealed an increase in the percentage change of flow compared to the baseline. This increase was linked to the variability of the climate under these conditions. As can be seen (Table 5-11) below, the calculated percentage change was found to be greater than the change seen between 1980 and 2010;

Table 5- 11: Percentage Change (2046 – 2076)

Period	***2046-2076***
Reference	**253**
MRCP 4_5	**232.9**
MRCP 8_5	**192.3**
%CHANGE 4.5	**7.9**

The computations showed that the RCP 8.5 projection led to a bigger percentage change than that of the RCP 4.5 projection, which was to be expected given that the RCP 8.5

projection represents the highest concentration pathway scenario that does not include particular climate mitigation policies.

Figure 5-19 above depicted flows relative to the baseline flow (calibration) under the RCP 4.5 projection between the years 1980 and 2010, whereas Figure 5-20 depicted relative flow under RCP 4.5 between the years 2046 and 2076, and this period showed higher effects on the flow when compared to the period depicted in Figure 5-19, which covered the years 1980 to 2010. The similar result was found when comparing the years 1980 to 2010 and 2046 to 2076 using RCP 8.5; however, the results showed an increase in relativeness for the latter period, as can be shown in Table 5-12 below.

Table 5- 12: Stream flow relative to reference period between the years 2046 - 2076

Scenario	***Sum***	***Minimum***	***Maximum***	***Mean***	***Median***	***SD***	***RMS***
Calibration	0	0	0	0	0	0	0
MRCP 4_5	-7530	-598.7	497.2	-20.2	-10	159.9	161
MRCP 8_5	-22593.1	-929	639.7	-60.7	-5.6	299.1	304.8

The RCP 4.5 and RCP 8.5 climate models were both applied to the model and run for the time period between 1980 and 2010 (Table 5-13), and the results showed that there were no significant variations in the maximum temperatures.

Table 5- 13: Temperature from the 1980 - 2010

SCENARIO	***MINIMUM***	***MAXIMUM***	***MEAN***	***MEDIAN***	***SD***	***RMS***	***%CHANGE***
CALIBRATION	15.7	23	19.6	20.1	2.1	19.7	0
MRCP 4_5	22	23	22.6	22.6	0.3	22.6	15.31
MRCP 8_5	22	23.1	22.6	22.6	0.3	22.6	15.31

As can be seen in Table 5-14 below, the findings indicated that there was a marginal rise in maximum temperature between the years 2046 and 2076 for both the RCP 4.5 and RCP 8.5 scenarios.

Table 5- 14: Temperature between the period 2046 - 2076

Scenario	**Minimum**	**Maximum**	**Mean**	**Median**	**SD**	**RMS**	**%Change**
Calibration	15.7	23	19.6	20.1	2.1	19.7	0
MRCP 4_5	23.8	24.8	24.2	24.2	0.2	24.2	23.47
MRCP 8_5	24.1	25.9	25	25	0.5	25	27.55

CHAPTER 6: DISCUSSION OF FINDINGS, CONCLUSION AND STUDY RECOMMENDATION

6.0 Introduction

This section presents the study's findings, draws its implications, and offers suggestions for applying WEAP as a modelling tool.

6.1Discussion of findings

6.1.1 Modelling water allocation using WEAP

Only 16 of the gauging stations in the Kafue basin were verified and utilized to set the model's parameters. Some of the stations with missing historical data also had flow discharge measurements taken to verify the reliability of the observations. Data from hydro-meteorological stations, evaporation rates, and inflow and return flow rates to the river system in the Kafue basin were all factored into the evaluations. Out of a total of 65 sites tracked by WARMA, only 22 are Telemetric Stations in the Kafue basin, transmitting data to a central location for analysis. Itezhi tezhi Dam, owned and operated by ZESCO Power Company, receives an average flow of 301 m^3/s from the middle Kafue basin, located roughly 270 km from the Kafue Gorge lower. Each year, around 27 million m^3 of water flows back into the middle Kafue basin. According to Chomba, M.J. and Nkhata, B.A. (2016), evaporation in the middle Kafue basin ranges from 1,605 millimeters to 2,166 millimeters per year, whereas the national average is 2,061 millimeters. According to projections, the average outflow into Kafue Gorge Dam (KGD) is 289 m^3/s. In order to simulate the WEAP model, the inflow into the Kafue basin was input and was modelled together with flows from its tributaries. The obtained data from CORDEX, which included mean precipitation and temperature values, was then used to set the model to run under natural flow circumstances in order to show the simulated flows.

GIS data sets were incorporated into the WEAP model. Files for gauge stations and hydrological basins were included as both vector (shape and feature classes) and raster (Grids) formats. The WEAP model was able to replicate flows into and out of the Middle Kafue Basin since the inflow was observed at the first sub-basin of the Middle Kafue Basin and the outflow was observed at the outlet, Lower Kafue Catchment. The analysis showed a 24.6% decrease in flows. Evaporation and demand points were input into the model, accounting for the majority of the change in flow. This demonstrates that the model can accurately simulate flows, making it suitable for use in river flow simulations.

6.1.2 Effects of climate change on water allocation

From the findings RCP 4.5, the simulated climate Model in WEAP showed a decrease in flows between the years 1980 and 2010 and the years 2046 and 2076, compared to the reference period. For both the 1980–2010 and the 2046–2076 time periods, RCP 8.5 was the same in comparison to the baseline. The margin of error in the rainfall data was calculated to be 6.0 when the 95% confidence interval was considered. The higher percentage change of flow from baseline was attributed to the effects of climate variability. The calculated percentage increase was found to be greater for the period 2046 to that of 2076 than the increase seen between 1980 and 2010 under RCP 8.5 and since RCP 8.5 represents the highest concentration pathway scenario that does not include particular climate mitigating actions, the projections based on this scenario showed a larger percentage shift than those based on RCP 4.5. Maximum temperature variations between the RCP 4.5 and RCP 8.5 climate models for the period 1980–2010 were found to be negligible.

6.2 Conclusion

The WEAP model has the ability to assess the future water demands and water balances which in turn leads to improvements in water allocation practices. Thus, using WEAP would be an efficient way to guarantee the water resources along the Kafue basin are managed in an integrated and sustainable manner, considering the various sectors that depend on the water. The WEAP simulation, which employed mass balance principles to allocate the Kafue basin's water resources, confirmed that both the RCP 8.5 and M-RCP 4.5 scenarios' impacts on the basin's water availability are real. Using an average of eight different climate models, the final two models i.e. RCP 4.5 and RCP8.5 were utilized to draw conclusions. Reduced flows along the Kafue basin were observed for all RCPs across all models, and this information is crucial for assessing future water demands and water balance within the basin. Small discrepancies in projected temperatures between the RCPs for the period 1980 and 2010 were attributed to natural climate variability, but larger discrepancies between 2046 and 2076 were attributed to climate change brought on by increasing Green House Gas (GHG) emissions.

In order to ensure efficient administration of the basin's water resources, the model is a tool that must be updated with new data whenever a customer applies for a permit to extract water from the Middle Kafue Basin or the Basin as a whole.

6.3 Recommendations

The research identifies a number of different research methods that should be utilized to facilitate the operationalization and enhancement of the WEAP model's implementation. The following suggestions are offered as possible solutions.

i. The results will be disseminated to the various catchment offices so that they may be utilized as a tool for the efficient management of the available water resources.

ii. It is recommended that this tool could be used to inform decision makers on the impacts of climate change and mitigation strategies, as well as to inform the process of water allocation.

iii. In order to characterize areas in the Kafue basin that might be stressed, it would be necessary to completely map both the existing users as well as the new users. If this were done, it would be easy to monitor and involve stakeholders in an integrated approach towards the goal of effective management of the water resources.

iv. The existing system of water allocation should encourage the most efficient use of available water resources and should also help individuals improve the ways in which they distribute water in their daily lives. The utilization of this model instrument would give an efficient means of ensuring that the water resource is managed in an integrated and sustainable manner in the event that it was to be used.

v. This tool can give the assistance necessary for analysing the impact of many alternative water allocation policy scenarios, which can help achieve positive economic outcomes in reducing poverty and environmental outcomes through integrated water management.

vi. The utilization of this tool would allow for the efficient water allocation and planning in the Kafue Basin. This is possible due to the fact that the tool provides a resource that could also be used in the other catchments in order to achieve the same goal of assessing future water demands and water balance.

vii. There is a need for such knowledge to be disseminated in order to fully appreciate it in terms of its applicability. Additionally, in order to fully appreciate the full extent of WEAP modelling, training should be provided in WEAP modelling and data analysis in institutions that have the mandate in water resources management, including learning institutions.

viii. The best approach that should be taken in order to fully manage Water Resource is to collect data related to the climate, monitor the impacts of climate change, and move from the development of adaptation plans to their implementation by the institutions that are mandated in water resources management.

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APPENDICES

Appendix 1: WATER PERMIT VERIFICATION FORM

WATER PERMIT VERIFICATION DOCUMENTATION FORM

The Director General Water Resources Management Authority (WRMA) PO Box 51059, Lusaka (<u>*place a logo here*</u>)	**WATER PERMIT VERIFICATION DOCUMENTATION FORM** *-surface water-*	*For Official Use Only*	File No:______________ CC:____________________ SCC:___________________

Water Permit Holder's General Information

Name of the applicant:

____

Business Name:

____

Applicant Type:

☐ Corporation	☐ Central Government
☐ Individual	☐ Municipal Government
☐ Partnership	☐ Provisional Government
☐ Sole Proprietor	☐ Other (*describe*): ____

1. **GENERALINFORMATION**

2. **PHYSICAL & MAILING ADDRESS**

Street Name:

Post Office Box Number:	Private Bag Number:	Postal Code:
Town/City:	District:	Province:

Telephone Contact (Landline):

Telephone Contact (Mobile):

Email Contact:

1. Water Right Number and file number (if known)		
2. Catchment Number		
3. Volume of water being abstracted in a day (liters or m^3)	Claimed Amount	Verified Amount
4. The water source from which the abstraction is made;		
5. Obtain type of water use (irrigation, industrial, mining, hydropower, domestic)		
6. Estimate of size, extent, of area, being irrigated (for water right holders doing irrigation agriculture)		
7. Record any existing hydraulic structures constructed for the enjoyment of the right granted under the repealed Act.		
8 Check status of such hydraulic structure or any civil works and note any alterations made(if such info is missing obtain the ‘as-built design’ drawings)		
9 Obtain data on storage capacity, size and their		

10 Obtain the GPS location of property with regards to water utilisation, in terms of; (a) Point of abstraction or diversion and/or- (b) Point of storage (c) Point of use/distribution (d) Map and GPS coordinates (***please submit a 1:50,000 map sheet***)	
11 Note existence of any easement attached to this water permit? If so, please provide the copy of the easement.	
12 Obtain comments on the water system situation	
13 Interview water right holder on any issue relevant to water use etc and record the proceedings therefrom.	

Declaration by Field Verification Personnel

I hereby certify that the information I have collected from property owner and recorded in this documentation form is true and correct, to the best of my knowledge.

Signature of the WARMA Assessment Personnel …………………Date………

Appendix 2: Climate Data Source, Projected Rainfall, RCP 4.5, Source (SMHI, 2016)

i. Appendix 2A: Projected Rainfall Data, RCP 4.5

Year	Sub-Basin							
	CF 1	cc F 3	c Lower K	S	flat 2	ccf 4	cf 5	Q
1951	798.32	1483.23	1447.45	1335.83	1259.33	1254.98	1505.65	1529.72
1952	760.21	1295.25	1491.82	1395.38	1439.29	1172.76	1385.28	1327.89
1953	638.56	993.54	1273.4	1023.58	1084.16	940.66	1056.15	998.49
1954	815.53	1308.99	1228.13	1171.08	1102.62	1088.6	1238.1	1269.78
1955	862.74	1396.48	1390.82	1348.07	1348.85	1298.74	1376.76	1361.18
1956	836.38	1448.47	1818.38	1592.89	1602.01	1516.46	1588.71	1474.57
1957	1008.67	1411.6	1399.66	1393.27	1279.66	1442.21	1559.59	1492.51
1958	707.16	1212.03	1426.82	1310.05	1286.73	1133.6	1303	1143.36
1959	923.16	1002.86	1102.74	1061.47	978.79	1189.84	1113.8	1082.58
1960	745.76	1416.17	1623.79	1442.51	1549.83	1428.03	1420.98	1437.78
1961	749.93	1396.56	1529.29	1445.37	1408.73	1394.63	1493.95	1395.57
1962	606.69	1283.85	1260.94	1297.28	1227.6	1055.23	1251.74	1198.83
1963	689.82	1373.81	1497.43	1479.22	1355.29	1266.75	1510.47	1249.4
1964	675.66	1073.48	1231.41	1081.08	1086.66	1173.41	1090.74	999.13
1965	864.89	1270.57	1318.52	1212.71	1298.5	1170.15	1260.97	1349.92
1966	595.69	1416.42	1457.76	1343.83	1311.43	1132.75	1399.85	1375.6
1967	688.46	1226.42	1255.84	1242.88	1142.24	988.73	1297.2	1229.71
1968	853.98	1265.42	1090.71	1120.28	1014.97	1051.96	1215.2	1359.08
1969	797.59	1335	1149.45	1124.66	1128.54	1139.86	1211.94	1374.55
1970	606.54	1125.62	1329.98	1239.85	1183.46	1088.64	1198.73	1056.36
1971	813.16	1087.93	1263.88	1229.58	1245.39	1103.25	1186.07	1163.83
1972	841.39	1141.85	1016.32	1058.86	984.1	883.69	1055.32	1104.94
1973	1124.9	1621.46	1567.9	1507.33	1527.42	1475.31	1524.22	1503.44

	Sub-Basin							
Year	CF 1	cc F 3	c Lower K	S	flat 2	ccf 4	cf 5	Q
1974	659.95	1234.05	1433.9	1277.66	1234.47	1217.11	1449.97	1300.19
1975	787.02	1398.41	1390.78	1287.93	1191.88	1130.23	1277.9	1362.95
1976	895.24	1224.46	1313.78	1266.01	1280.01	1135.65	1271.88	1207.98
1977	748.04	1163.76	1543.92	1328.72	1409.61	1252.76	1292.51	1186.68
1978	725.67	1276.11	1350.14	1297.15	1229.96	1188.08	1433.03	1289.57
1979	757.49	1203.32	1185.81	1191.18	1180.37	1110.86	1238.23	1069.28
1980	450.11	960.93	1118.4	957.71	993.35	779.63	1031.86	956.82
1981	908.42	1393.3	1370.24	1396.08	1294.73	1147.97	1434	1348.25
1982	654.47	1266.64	1338.68	1261.95	1179.83	1062.5	1276.69	1220
1983	728.47	1325.73	1801.62	1437.62	1521.77	1478.55	1453.03	1359.1
1984	816.36	1115.29	1520.26	1277.13	1421.11	1259.48	1257.35	1095.26
1985	650.31	1246.3	1319.52	1235.76	1154.72	1199	1341.49	1283.94
1986	648.45	1150.61	1411.45	1201.51	1258.92	940.79	1131.48	1112.04
1987	770.29	1287.16	1225.83	1194.41	1202.51	1178.43	1245.36	1245.94
1988	815.12	1172.88	1209.46	1147.67	1138.98	1159.63	1219.92	1267
1989	603.06	1399.35	1165.14	1147.39	1109.39	976.88	1269.43	1281.22
1990	802.75	1252.3	1226.55	1200.44	1149.07	1263.93	1255.99	1228.03
1991	935.27	1101.5	1175.19	1074.85	1068.86	1224.71	1153.47	1276.61
1992	718.86	1259.47	1423.66	1344.3	1323.3	1174.6	1334.18	1304.77
1993	667.41	1102.07	1282.01	1182.11	1175.6	1139.05	1209.88	1059.13
1994	877.61	1290.5	1408.23	1427	1372.44	1302.21	1468.91	1302.66
1995	545.53	1340.83	1331.45	1243.52	1222.51	1081.94	1316.91	1355.78
1996	605.39	957.28	1245.05	1042.02	1073.46	967.18	1067.36	981.03
1997	759.24	1487.97	1378.59	1346.61	1228.98	1255.89	1421.84	1414.08
1998	834.46	1535.59	1426.17	1337.77	1303.86	1269.32	1457.87	1483.76
1999	796.81	1369.09	1468.02	1450.52	1357.23	1297.4	1487.54	1349.49
2000	650.11	1180.08	1268.64	1206.16	1186.33	1036.6	1228.24	1250.88

Year	Sub-Basin							
	CF 1	cc F 3	c Lower K	S	flat 2	ccf 4	cf 5	Q
2001	731.18	1317.66	1341.34	1303.34	1172.97	1160.13	1332.23	1351.65
2002	619.94	1315.78	1397.86	1347.66	1299.22	1201.31	1305.95	1258.29
2003	706.2	1136.72	1293.04	1158.92	1121.1	1210.37	1170.31	1124.67
2004	703.8	1281.37	1060.51	1090.55	1061.03	1162.56	1119.5	1118.57
2005	675.98	1374.31	1417.71	1386.18	1406.64	1223.31	1474.23	1413
2006	693.98	1123.78	1509	1227.02	1303.45	1289.17	1310.26	1219.95
2007	721.44	1341.66	1401.94	1334.66	1296.71	1172.9	1407.96	1321.23
2008	812.8	1297.43	1228.7	1353	1272.73	989.78	1349.64	1294.71
2009	657.52	1126.39	1414.91	1141.14	1205.07	1237.12	1176.2	1075.34
2010	725.3	1275.15	1272.27	1213.58	1209.68	1181.5	1209.15	1191.4
2011	652.56	1339.05	1334.53	1272.58	1206.37	1127.19	1351.35	1256
2012	843.6	1410.1	1462.21	1386.87	1358.55	1373.34	1483.16	1388.15
2013	859.35	1324.37	1376.01	1226.81	1237.77	1270.45	1253.13	1319.67
2014	603.52	1203.05	1237.92	1167.7	1115.52	1168.75	1226.92	1153.69
2015	669.3	1260.83	1189.93	1154.27	1096.58	1042.5	1202.04	1221.22
2016	602.12	1132.1	1439.48	1136.36	1234.29	1039.81	1094.1	1022.35
2017	477.32	1337.18	1317.25	1384.6	1386.64	1125.53	1430.17	1404.46
2018	649.98	1355.62	1392.78	1452.24	1377.47	1117.87	1473.6	1326.67
2019	488.59	1112.39	1207.66	1057.53	1046.48	1032.05	1126.42	1126.85
2020	724.96	1190.35	1471.67	1282.49	1286.15	1306.33	1284.97	1114.25
2021	760.53	1331.71	1679.87	1410.9	1343.98	1580.43	1503.63	1406.15
2022	556.02	1251.97	1358.59	1265.23	1221.78	1001.82	1309.41	1201.23
2023	499.06	1217.33	1255.27	1269.02	1247.62	1191.52	1293.18	1270.99
2024	687.32	1049.68	1293.9	1121.55	1123.33	1049.92	1138.13	1072.36
2025	953.54	1271.35	1506.14	1363.97	1336.84	1314.07	1375.43	1299.08
2026	846.6	1465.44	1449.24	1509.22	1429.05	1209.1	1582.53	1406.17
2027	510.73	1078.48	1280.31	1176.8	1171.14	876.24	1125.74	1083.11

Year	Sub-Basin							
	CF 1	cc F 3	c Lower K	S	flat 2	ccf 4	cf 5	Q
2028	627.42	1219.97	1389.55	1311.54	1255.58	1116.25	1427.73	1274.45
2029	653.14	1130.93	1407.6	1357.84	1304.12	1165.14	1387.86	1104.5
2030	851.74	1419.76	1425.05	1389.62	1337.08	1376.44	1422.06	1472.15
2031	802.17	1455.91	1420.38	1437.01	1416.23	1144.87	1482.88	1491.37
2032	682.58	1456.85	1336.75	1323.38	1298.75	1174.68	1347.07	1338.65
2033	698.68	1516.65	1421.71	1414.46	1421.25	1205.21	1431.08	1409.41
2034	846.94	1314.22	1272.36	1257.27	1202.76	1195.94	1283.15	1217.78
2035	774.86	1394.46	1407.93	1485.6	1353.99	1223.49	1618.05	1493.03
2036	733.09	1099.61	1425.07	1167.15	1189.19	1103.44	1241.92	1234.9
2037	825.67	1361.3	1274.8	1267.13	1240.96	1132.77	1268.55	1307.66
2038	942.29	1251.72	1462.6	1327.71	1286.07	1329.16	1376.84	1284.31
2039	515.62	1595.28	1467.46	1388.38	1359.89	1110.12	1463.55	1430.43
2040	679.2	1206.45	1242.41	1070.28	1030.9	1177.81	1166.03	1130.22
2041	918	1347.94	1411.62	1428.18	1360.65	1119.69	1527.46	1420.62
2042	761.33	1524.78	1474.06	1406.35	1362.66	1271.77	1564.81	1436.37
2043	733.15	1576.45	1443	1326.27	1253.24	1209.7	1433.25	1462.31
2044	683.1	1353.76	1430.89	1375.02	1364.42	1088.99	1370.81	1248.24
2045	600.49	1205.17	1113.53	1218.38	1144.77	1036.5	1333.02	1262.5
2046	498.8	1141.59	1355.85	1135.75	1262.7	1056.12	1133.7	1187.79
2047	548.76	1380.28	1373.53	1367.03	1328.72	1233.88	1423.29	1376.17
2048	754.56	1457.78	1369.96	1365.39	1384.74	1151.76	1339.78	1323.18
2049	599.17	1341.91	1460.63	1422.86	1395.22	1195.74	1407.77	1223.23
2050	591.42	1382.48	1467.47	1353.45	1305.49	1165.37	1446.2	1271.8
2051	612.14	1227.99	1235.89	1209.72	1235.98	1087.17	1238.41	1139.42
2052	600.1	1196.82	1226.42	1176.96	1192.86	981.99	1231.36	1161.57
2053	848.36	1379.73	1230.37	1185.53	1086.11	1228.56	1209.24	1283.44
2054	864.16	1382.29	1150.58	1245.93	1135.29	1114.1	1305.65	1360.44

Year	Sub-Basin							
	CF 1	cc F 3	c Lower K	S	flat 2	ccf 4	cf 5	Q
2055	676.36	1271.9	1416.49	1430.47	1372.69	1066.31	1460.59	1291.82
2056	667.25	1101.31	1364.17	1252.02	1280.33	1204.84	1178.82	1001.38
2057	607.1	1089.36	1202.89	1227.71	1131.66	1114.1	1177.79	1091.88
2058	850.34	1227.76	1272.93	1181.87	1148.83	1266.25	1217.76	1279.29
2059	649.94	1121.25	1197.94	1073.6	1046.2	984.56	1069.96	1071.91
2060	611.99	1396.66	1338.65	1295.65	1259.1	1222.76	1395.26	1453.11
2061	687.03	1433.98	1632.27	1458.07	1457.49	1272.61	1518.29	1383.76
2062	659.95	1102.94	1148.04	1060.4	1134.17	965.77	1027.27	1026.95
2063	608.84	1351.52	1361.03	1265.72	1205.65	1093.43	1343.62	1307.58
2064	552.5	1067.29	1266.16	1218.22	1224.68	966.8	1114.65	1018.62
2065	602.52	1484.44	1446.24	1359.22	1365.83	1092.51	1376.15	1414.37
2066	566.09	1362.48	1562.21	1486.02	1445.91	1368.05	1447.54	1294.51
2067	502.27	1414.04	1503.15	1404.2	1359.13	1299.16	1462.12	1378.56
2068	551.04	1257.89	1266.04	1177.2	1228.23	1004.28	1139.91	1148.31
2069	534.86	1087.79	1395.42	1210.19	1326.06	1092.31	1131.16	1035.87
2070	682.05	1325.68	1404.2	1326.69	1325.64	1137.27	1336.87	1280.36
2071	670.81	1264.01	1130.97	1130.94	1109.19	940.81	1157.72	1150.24
2072	555.12	1403.16	1387.32	1375.88	1317.52	1209.09	1389.88	1226.45
2073	742.34	1300.57	1403.11	1268.5	1256.03	1466.31	1297.53	1231.85
2074	810.28	1362.88	1434.38	1415.64	1279.7	1252.39	1483.59	1448.79
2075	687.16	1140.94	1175.4	1074	1050.03	936.42	1165.25	1161.15
2076	1007.07	1559.88	1618.99	1533.31	1396.33	1408.17	1615.42	1534.05
2077	536.39	1042.2	1206.06	1007.12	1079.18	969.55	1046.71	1053.5
2078	528.4	1244.52	1067.02	1269.86	1201.13	884.2	1294.91	1189.87
2079	568.41	1388.93	1523.56	1455.81	1431.61	1235.25	1497.47	1381.63
2080	666.84	1137.82	1381.02	1173.16	1127.6	1024.95	1235.61	1136.71
2081	625.69	1091.35	1344.96	1212.07	1239.88	1058.74	1214.73	1078.52

Year	Sub-Basin							
	CF 1	cc F 3	c Lower K	S	flat 2	ccf 4	cf 5	Q
2082	681.5	1017.37	1481.09	1219.97	1313.05	1208.23	1204.78	1075.11
2083	642.44	1319.25	1436.96	1418.2	1385.16	1313.72	1453.55	1321.1
2084	487.92	956.8	1232.35	998.3	1078.38	936.97	992.15	969.71
2085	663.32	1493.94	1364.05	1524.47	1315.05	1332.35	1665.66	1433.63
2086	586.97	1229.11	1427.99	1241.98	1309.61	1207.17	1207.33	1149.74
2087	678.86	1214.52	1226.14	1061.17	1050.71	1032.48	1131.82	1215.81
2088	753.72	1066.31	1154.91	1028.53	1002.2	1070.67	1105.05	1169.45
2089	643.75	1233.12	1397.33	1206.28	1181.52	1101.38	1293.21	1158.87
2090	718.45	1491.72	1437.57	1354.12	1246.77	1277.03	1496.81	1493.68
2091	973.5	1696.87	1445.54	1593.9	1383.59	1336.26	1757.61	1668.97
2092	658.07	1528.33	1341.52	1310.31	1203.43	1117.94	1388.18	1478.29
2093	543.15	785.06	878.96	773.86	824.93	822.02	774.43	816.61
2094	682.7	1112.31	1412.83	1230.9	1351.94	1200.8	1162.78	1155.26
2095	700.75	1205.7	1427.92	1342.96	1262.02	1248.44	1390.83	1223.4
2096	613.96	1277.29	1236.82	1195.53	1088.32	1011.69	1238.36	1287.9
2097	574.17	1270.36	1245.5	1200.3	1222.67	1072.79	1262.27	1306.23
2098	511.94	1135.99	1329.82	1262.95	1175.54	1005.04	1271.49	1080.59
2099	531.58	827.54	1107.28	839.37	893.88	698.33	858.93	819.17
2100	913.24	1432.01	1413.82	1455.16	1397.3	1412.39	1506.08	1415.89

ii. Appendix 2$_B$: Projected Rainfall Data, RCP 4.5

Year	Sub-Basin							
	L 1	R	p	O	j	N1	C I	C G
1951	907.32	1502.62	1536.05	1509.63	1505.65	1422.13	1529.72	1503.85
1952	810.08	1360.12	1253.37	1312.56	1385.28	1271	1327.89	1398.14
1953	647.07	1023.68	885.09	1057.67	1056.15	1011.82	998.49	1132.16
1954	847.63	1273.12	1106.93	1189.3	1238.1	1393.2	1269.78	1241.76
1955	985.9	1402.78	1258.83	1297.02	1376.76	1339.93	1361.18	1359.96
1956	812.39	1531.12	1304.5	1698.82	1588.71	1488.63	1474.57	1700.58
1957	956.04	1497.66	1385.66	1527.12	1559.59	1449.34	1492.51	1538.89
1958	684.78	1257.08	1040.5	1104.84	1303	1146.34	1143.36	1354.28
1959	954.63	1084.03	1019.76	1175.44	1113.8	1070.08	1082.58	1119.82
1960	744.39	1459.6	1341.8	1563.48	1420.98	1474.02	1437.78	1516.7
1961	840.62	1505.27	1310.2	1364.04	1493.95	1331.29	1395.57	1441.67
1962	591.63	1281.15	1031.37	1120.26	1251.74	1233.36	1198.83	1274.65
1963	751.43	1493.12	1140.34	1507.9	1510.47	1186.41	1249.4	1549.11
1964	687.7	1095.15	988.92	1048.85	1090.74	968.82	999.13	1126.75
1965	903.35	1354.35	1051.37	1179.01	1260.97	1348.19	1349.92	1238.09
1966	660.34	1410.83	1128.07	1231	1399.85	1369.58	1375.6	1410.12
1967	674.28	1336.57	1039.48	1198.94	1297.2	1136.52	1229.71	1263.77
1968	807.39	1248.52	1028.6	1088.85	1215.2	1374.21	1359.08	1188.38
1969	898.45	1279.65	1254.57	1166.33	1211.94	1512.61	1374.55	1275.62
1970	705.71	1183.52	1071.41	1193.32	1198.73	1084.15	1056.36	1270.61
1971	810.03	1199.39	1049.58	1155.68	1186.07	1124.95	1163.83	1192.13
1972	858.92	1126.31	1064.05	996.34	1055.32	1156.28	1104.94	1059.45
1973	1050.17	1600.19	1486.18	1590.65	1524.22	1552.32	1503.44	1501.88
1974	790.42	1367.51	1350.42	1367.05	1449.97	1229.33	1300.19	1512.17
1975	807.99	1338.82	1124.77	1181.26	1277.9	1408.27	1362.95	1299.76
1976	878.6	1266.45	1155.19	1256.2	1271.88	1224.79	1207.98	1324.59

Year	Sub-Basin							
	L 1	R	p	O	j	N1	C I	C G
1977	739.88	1253.21	1160.71	1356.34	1292.51	1124.67	1186.68	1374.44
1978	782.07	1405.79	1099.34	1194.27	1433.03	1183.43	1289.57	1398.09
1979	772.02	1226.74	1030.3	1187.17	1238.23	1100.19	1069.28	1289.96
1980	604.9	1021.96	887.5	1036.64	1031.86	918.79	956.82	1108.6
1981	914.74	1458.05	1101.34	1253.98	1434	1305.52	1348.25	1443.32
1982	794.97	1332.42	1063.54	1191.82	1276.69	1242.08	1220	1257.18
1983	693.58	1428.76	1295.3	1609.06	1453.03	1279.23	1359.1	1575
1984	813.49	1194.25	1117.58	1302.54	1257.35	1094.18	1095.26	1382.23
1985	735.79	1334.1	1200.54	1249.17	1341.49	1258.17	1283.94	1325.21
1986	684.11	1189.82	981.48	1051.26	1131.48	1051.08	1112.04	1146.37
1987	914.64	1307.58	1157.49	1247	1245.36	1318.17	1245.94	1235.04
1988	863.15	1241.08	1090.44	1167.27	1219.92	1178.92	1267	1233.3
1989	751.29	1380.98	1099.69	1171.14	1269.43	1325.07	1281.22	1217.07
1990	903.1	1280.97	1141.32	1183.02	1255.99	1203.63	1228.03	1276.28
1991	880.83	1168.26	1111.42	1136.01	1153.47	1200.56	1276.61	1167.04
1992	799.72	1347.04	1161.22	1295.16	1334.18	1245.32	1304.77	1332.63
1993	662.59	1172.34	1002.93	1185.65	1209.88	1047.32	1059.13	1241.87
1994	891.64	1374.82	1207.81	1310.68	1468.91	1262.1	1302.66	1477.77
1995	713.12	1363.45	1219.48	1137.14	1316.91	1358.92	1355.78	1309.58
1996	602.35	1010.87	951.92	1045.99	1067.36	966.17	981.03	1120.17
1997	886.76	1496.09	1255.76	1384.84	1421.84	1412.2	1414.08	1393.84
1998	849.82	1543.61	1396.64	1399.46	1457.87	1548.27	1483.76	1437.34
1999	855.01	1436.5	1275.94	1377.24	1487.54	1348.21	1349.49	1530.51
2000	771.47	1237.81	1187.12	1149.08	1228.24	1256.19	1250.88	1278.33
2001	780.42	1329.39	1239.05	1241.97	1332.23	1358.96	1351.65	1384.82
2002	753.38	1371.8	1171.23	1164.98	1305.95	1257.6	1258.29	1279.73
2003	831.69	1190.72	1089.63	1237.22	1170.31	1080.84	1124.67	1146.67

Year	Sub-Basin							
	L 1	R	p	O	j	N1	C I	C G
2004	729.08	1206.04	994.03	1179.27	1119.5	1168.42	1118.57	1105.36
2005	819.66	1441.39	1261.47	1259.72	1474.23	1430.54	1413	1441.43
2006	766.56	1236.94	1172.27	1369.24	1310.26	1143.81	1219.95	1387.3
2007	779	1435.02	1191.46	1306.59	1407.96	1312.54	1321.23	1432.05
2008	914.99	1302.84	1209.69	1146.31	1349.64	1355.76	1294.71	1351.96
2009	637.54	1145.25	975.64	1225.85	1176.2	1037.87	1075.34	1203.87
2010	920.61	1236.43	1095.58	1204.86	1209.15	1194.96	1191.4	1246.73
2011	824.55	1331.87	1092.08	1246.43	1351.35	1346.02	1256	1337.37
2012	995.66	1467.27	1302.03	1327.44	1483.16	1364.42	1388.15	1458.23
2013	1002.51	1287.33	1190.42	1247.03	1253.13	1346.1	1319.67	1317.67
2014	632.07	1207.4	1099.96	1191.93	1226.92	1159.56	1153.69	1299.45
2015	677.99	1258.1	1166.32	1135.92	1202.04	1235.82	1221.22	1196.29
2016	638.93	1138.65	1009.55	1212.47	1094.1	1029.02	1022.35	1233.64
2017	664.96	1383.77	1242.08	1248.38	1430.17	1368.29	1404.46	1442.52
2018	740.54	1440.36	1194.68	1244.49	1473.6	1329.81	1326.67	1448.58
2019	628.21	1143.59	1090.11	1137.64	1126.42	1180.78	1126.85	1178.37
2020	776.19	1219.64	1080.55	1310.59	1284.97	1127.48	1114.25	1374
2021	882.49	1421.93	1249.94	1695.79	1503.63	1361.24	1406.15	1617.95
2022	628.63	1291.49	1050.26	1169.46	1309.41	1209.08	1201.23	1335.51
2023	497.91	1297.54	1111.71	1176.4	1293.18	1233.27	1270.99	1253.37
2024	732.53	1097.06	1019.93	1115.04	1138.13	1024.52	1072.36	1180.2
2025	1063.17	1322.47	1239.76	1407.28	1375.43	1291	1299.08	1465.65
2026	931.93	1512.39	1344.7	1385.94	1582.53	1388.99	1406.17	1660.57
2027	554.85	1127.46	987.62	1016.24	1125.74	1014.8	1083.11	1157.86
2028	619.15	1376.68	1127.12	1136.96	1427.73	1194	1274.45	1384.89
2029	703.23	1291.27	1141.49	1292.81	1387.86	1034.99	1104.5	1478.92
2030	1084.84	1405.43	1355.57	1409.15	1422.06	1445.28	1472.15	1451.47

	Sub-Basin							
Year	L 1	R	p	O	j	N1	C I	C G
2031	792.78	1525.88	1297.89	1328.96	1482.88	1482.93	1491.37	1510.11
2032	810.22	1408.67	1207.58	1286.81	1347.07	1447.53	1338.65	1358.45
2033	725.93	1499.52	1251.78	1322.24	1431.08	1439.05	1409.41	1397.78
2034	853.51	1316.56	1083.85	1227.72	1283.15	1247.63	1217.78	1326.43
2035	818.19	1540.73	1257.7	1399.38	1618.05	1363.41	1493.03	1579.63
2036	880.2	1166.71	1166.85	1200.76	1241.92	1217.54	1234.9	1294.07
2037	893.54	1307.69	1176.68	1190.35	1268.55	1391.17	1307.66	1274.38
2038	1045.91	1314.35	1242.33	1407.77	1376.84	1282.32	1284.31	1461.19
2039	717.93	1533.29	1192.41	1249.08	1463.55	1486.33	1430.43	1437.55
2040	764.45	1228.25	1075.34	1284.34	1166.03	1213.23	1130.22	1141.67
2041	931.58	1459.86	1239.48	1346.56	1527.46	1350.55	1420.62	1508.82
2042	881.87	1560.28	1259.59	1385.56	1564.81	1480.28	1436.37	1569.55
2043	765.58	1505.27	1312.59	1377.65	1433.25	1450.46	1462.31	1492.45
2044	678.19	1414.71	1029.78	1207.39	1370.81	1304.01	1248.24	1429.77
2045	683.54	1300.65	1025.86	1109.8	1333.02	1250.11	1262.5	1303
2046	622.14	1170.99	950.76	1106.51	1133.7	1210.1	1187.79	1180.29
2047	592.35	1441.36	1193	1305.79	1423.29	1400.99	1376.17	1353.58
2048	932.88	1404.7	1187.76	1163.6	1339.78	1351.28	1323.18	1302.42
2049	826.49	1345.67	1149.17	1311.67	1407.77	1287.42	1223.23	1517.56
2050	696.67	1445.49	1121.97	1362.52	1446.2	1218.39	1271.8	1421.83
2051	734.72	1234.33	1251.78	1143.91	1238.41	1141.5	1139.42	1266.24
2052	603.29	1222.64	982.39	1081.4	1231.36	1143.63	1161.57	1191.28
2053	969.35	1308.87	1147.11	1261.79	1209.24	1367.59	1283.44	1193.49
2054	1059.38	1396.84	1306.14	1170.1	1305.65	1476.89	1360.44	1289.82
2055	721.19	1396.53	1204.91	1248.72	1460.59	1239.69	1291.82	1465.56
2056	731.15	1158.14	933.54	1265.41	1178.82	1035.82	1001.38	1263.92
2057	670.62	1150.75	1078.21	1205.45	1177.79	1067.34	1091.88	1228.98

Year	Sub-Basin							
	L 1	R	p	O	j	N1	C I	C G
2058	1089.43	1299.57	1204.55	1305.35	1217.76	1278.61	1279.29	1218.63
2059	772.6	1126.77	975.69	1051.31	1069.96	1112.58	1071.91	1054.15
2060	733.84	1468.89	1412.96	1318.81	1395.26	1387.88	1453.11	1360.3
2061	733.23	1493.34	1264.8	1417.86	1518.29	1350.34	1383.76	1550.95
2062	733.69	1093	878.49	1019.1	1027.27	1109.46	1026.95	1055.76
2063	735.23	1374.61	1155.62	1256.48	1343.62	1348.61	1307.58	1387.82
2064	624.46	1060.11	899.82	1001.17	1114.65	1052.19	1018.62	1173.12
2065	844.65	1427.53	1115.67	1207.41	1376.15	1446.71	1414.37	1313.54
2066	720.46	1383.19	1289.96	1539.36	1447.54	1312.7	1294.51	1526.89
2067	721.49	1464.27	1319.53	1363.15	1462.12	1318.04	1378.56	1437.9
2068	635.13	1185.76	1006.14	1056.66	1139.91	1248.69	1148.31	1183.34
2069	577.96	1129.33	983.98	1171.74	1131.16	1048.23	1035.87	1231.57
2070	833.29	1350.5	1275.26	1187.46	1336.87	1293.82	1280.36	1397.98
2071	860.84	1201.54	1050.98	1008.29	1157.72	1275.18	1150.24	1132.38
2072	645.52	1398.27	1109.59	1292.32	1389.88	1307.57	1226.45	1373.28
2073	774.92	1300.87	1314.58	1414.02	1297.53	1260.9	1231.85	1342.47
2074	937.5	1480.05	1432.27	1373.55	1483.59	1384.03	1448.79	1491.97
2075	773.42	1196.47	1003.59	1069.09	1165.25	1198.36	1161.15	1183.71
2076	1005.82	1603.32	1397.2	1550.73	1615.42	1504.14	1534.05	1619.96
2077	671.59	1008.6	1051.16	1111.32	1046.71	1060.75	1053.5	1163.2
2078	582.36	1283.39	986.22	970.3	1294.91	1199.7	1189.87	1228.17
2079	582.41	1495.52	1222.9	1417.89	1497.47	1304.87	1381.63	1510.91
2080	643.58	1221.15	1035.76	1146.4	1235.61	1093.56	1136.71	1240.07
2081	683.63	1218.14	1030.86	1165.26	1214.73	991.41	1078.52	1277.07
2082	824.19	1129.79	1028.68	1207.25	1204.78	1030.81	1075.11	1274.9
2083	770.49	1414.95	1310.15	1332.71	1453.55	1310.1	1321.1	1494.32
2084	570.27	1006.75	914.13	1037.39	992.15	1006.1	969.71	1100.44

Year	Sub-Basin							
	L 1	R	p	O	j	N1	C I	C G
2085	753.23	1590.46	1332.16	1547.96	1665.66	1472.19	1433.63	1724.35
2086	642.5	1235.71	977.98	1133.52	1207.33	1173.53	1149.74	1209.4
2087	757.66	1191.74	1111.36	1120.59	1131.82	1262.12	1215.81	1174.06
2088	817.63	1100.36	1098.34	1130.95	1105.05	1099.38	1169.45	1134.54
2089	719.57	1268.02	1074.19	1208.38	1293.21	1207.74	1158.87	1311.49
2090	858.98	1485.17	1276.67	1378.33	1496.81	1503.91	1493.68	1479.86
2091	1125.18	1765.29	1545.59	1517.5	1757.61	1626.44	1668.97	1695.54
2092	768.7	1457.08	1144.85	1221.83	1388.18	1543.47	1478.29	1368.69
2093	546.69	777.67	834.19	825.53	774.43	845.06	816.61	841.68
2094	837.73	1161.97	1051.45	1256.23	1162.78	1142.16	1155.26	1266.32
2095	803.62	1308	1118.79	1299.5	1390.83	1211.71	1223.4	1440
2096	729.43	1266.44	1106.44	1138.16	1238.36	1378.26	1287.9	1260.23
2097	689.87	1260.55	1010.83	1081.45	1262.27	1321.68	1306.23	1198.13
2098	575.79	1284.39	1017.99	1124.47	1271.49	1050.22	1080.59	1226.85
2099	557.54	859.22	702.47	815.87	858.93	887.79	819.17	904.01
2100	785.19	1472.96	1314.19	1451.2	1506.08	1348.3	1415.89	1516.76

iii. Appendix 2C: Projected Rainfall Data, RCP 4.5

Year	Sub-Basin							
	k	I	E	F	H	M	C N d	A
1951	1503.85	1184.31	1546.55	1241.42	1461.47	953.77	1374.96	1127.22
1952	1398.14	997.42	1347.66	1024.63	1227.76	848.37	1283.65	930.63
1953	1132.16	685.51	1024.14	711.19	845.21	546.7	994.77	630.74
1954	1241.76	1179.51	1216.14	960.02	1084.73	858.55	1130.96	1145.47
1955	1359.96	966.38	1344.27	941.7	1154.69	872.07	1317.98	959.66
1956	1700.58	931.97	1454.83	984.83	1236.6	815.25	1554.03	859.32
1957	1538.89	1150.31	1522.81	1186.71	1339.3	1017.14	1524.48	1109.76
1958	1354.28	811.48	1139.22	762.69	956.8	644.93	1077.13	732.07
1959	1119.82	914.75	1087.33	794.45	972.55	790.64	1141.27	910.21
1960	1516.7	1053.12	1366.15	1029.17	1243.63	749.66	1521.11	981.08
1961	1441.67	1093.6	1455	1036.06	1201.82	799.35	1360.8	1042.57
1962	1274.65	782.37	1133.2	702.39	912.77	540.12	1027.54	771.71
1963	1549.11	860.37	1250.43	875.18	1129.24	682.42	1343.48	859.99
1964	1126.75	812.86	1032.87	836.4	1004.46	549.2	1104.53	798.6
1965	1238.09	874.63	1245.2	895.37	1025.88	840.6	1141.79	966.41
1966	1410.12	1016.84	1319.29	817.91	1015.18	686.69	1145.87	913.54
1967	1263.77	849.57	1223.76	708.3	852.87	536.41	983.09	798.83
1968	1188.38	920.68	1235.24	816.35	966.05	653.69	1110.57	858.55
1969	1275.62	1011.86	1291.53	1046.7	1175.21	783.25	1176.4	920.89
1970	1270.61	866.45	1075.82	870.61	1095.37	675.31	1122.93	883.45
1971	1192.13	855.23	1170.77	812.06	1022.12	707.78	1127.18	793.36
1972	1059.45	977.71	1103.83	856.09	952.5	794.65	926.98	961.1
1973	1501.88	1163.17	1487.89	1105.21	1414.8	913.64	1549.07	1135.3
1974	1512.17	883.33	1381.1	978.91	1221.87	757.37	1283.91	809.98
1975	1299.76	1005.09	1202.05	956.59	1099.69	799.6	1140.24	986.26
1976	1324.59	907.21	1184.02	989.24	1182.78	861.14	1187.88	908.5

Year	Sub-Basin							
	k	I	E	F	H	M	C N d	A
1977	1374.44	873.58	1209.65	949.47	1158.52	711.39	1298.28	856.75
1978	1398.09	695.22	1328.86	784.27	958	629.14	1158.9	710.53
1979	1289.96	861.21	1142.83	818.71	984.87	614.51	1171.5	849.67
1980	1108.6	641.33	970.62	569.02	680.54	489.11	822.89	582.41
1981	1443.32	995.29	1279.32	874.51	1122.55	784.85	1186.83	955.63
1982	1257.18	890.87	1202.31	835.21	972.89	734.62	1092.9	875.47
1983	1575	874.42	1443.47	985.47	1282.64	672.68	1511.18	822.73
1984	1382.23	855.22	1175.52	899.1	1174.69	636.47	1277.25	802.54
1985	1325.21	892.24	1284.57	907.42	1121.58	689.73	1216.27	812.51
1986	1146.37	727.63	1117.1	698.93	899.91	615.77	924.31	690.93
1987	1235.04	951.3	1218.02	914.22	1118.31	675.53	1266.2	870.44
1988	1233.3	857.12	1223.35	837.54	981.53	741.93	1150.62	878.15
1989	1217.07	909.76	1239.21	907.37	1023.02	769.54	1034.4	840.85
1990	1276.28	1007.42	1244.62	986.73	1112.56	829.37	1263.22	1000.04
1991	1167.04	990.78	1190.7	903.38	1031.68	782.64	1207.6	965.42
1992	1332.63	1050.25	1289.76	1018.28	1135.79	846.2	1212.47	1011.24
1993	1241.87	786.7	1071.14	852.78	1053.55	672.38	1158.33	706.3
1994	1477.77	956.24	1388.79	961.87	1185.85	863.16	1315.76	886.94
1995	1309.58	870.01	1398.99	920.82	1126.47	770.89	1094.15	841.42
1996	1120.17	753.71	1031.61	661.96	879.67	484.04	997.14	750.67
1997	1393.84	1143.05	1417.67	1001.37	1236.76	790.33	1315.69	1101.59
1998	1437.34	1068.31	1480.64	1086.88	1267.3	851.65	1320.98	1023.34
1999	1530.51	1015.02	1416.99	1069.99	1167.43	901.4	1298.39	1045.38
2000	1278.33	989.66	1243.4	900.89	1041.15	699.07	1080.33	946.63
2001	1384.82	1101.84	1333.49	879.24	1028.73	643.73	1165.16	975.47
2002	1279.73	830.37	1254.17	844.24	1095.95	820.34	1185.26	788.98
2003	1146.67	854.43	1154.99	866.42	1090.38	802.37	1230.02	778.49
2004	1105.36	885.04	1089.62	817.39	1044.18	769.02	1260.56	888.66

Year	Sub-Basin							
	k	I	E	F	H	M	C N d	A
2005	1441.43	992.12	1437.99	930.13	1086.33	726.69	1222.22	1001.92
2006	1387.3	907.93	1225.97	926.27	1118.78	680.16	1274.7	867
2007	1432.05	973.63	1324.95	877.62	1091.88	713.16	1211.28	887.49
2008	1351.96	1218.29	1289.8	1064.47	1073.15	845.21	1057.97	1234.74
2009	1203.87	690.39	1126.51	791.83	1039.58	657.33	1265.52	659.71
2010	1246.73	1045.69	1144.55	892.2	1001.77	810.88	1163.6	1055.49
2011	1337.37	908.88	1243.8	897.81	972.82	755.86	1141.32	892.97
2012	1458.23	1272.27	1370.81	1202.97	1291.07	955.93	1414.03	1333.97
2013	1317.67	1113.41	1306.36	1033.33	1171.81	924.92	1267.7	1091.89
2014	1299.45	921.48	1133.81	920.8	1104.92	724.84	1275.86	821.52
2015	1196.29	852.94	1205.06	842.22	982.61	632.87	1068.79	822.54
2016	1233.64	771.82	1021.13	773.57	941.66	601.79	1085.43	725.12
2017	1442.52	913.55	1452.19	935.87	1113.95	701.74	1175.29	908.28
2018	1448.58	1115.01	1279.89	984.79	1127.87	712.53	1199.32	965.61
2019	1178.37	895.71	1112.96	858.76	961.56	647.1	993.87	762.92
2020	1374	916.05	1160.4	878.82	1084.91	714.1	1305.79	849.81
2021	1617.95	983.47	1443.27	994.79	1268.1	863	1637.31	976.26
2022	1335.51	792.28	1176.56	792.6	976.62	630.58	1111.37	727.09
2023	1253.37	766.71	1263	898.71	1151.42	522.91	1210.88	680.3
2024	1180.2	862.75	1115.79	818.88	941.72	638.15	1066.56	889.53
2025	1465.65	1142.79	1289.24	1069.18	1260.64	860.46	1363.88	1051.44
2026	1660.57	994.39	1506.56	1012.86	1281.75	966.82	1292.05	958.66
2027	1157.86	705.38	1055.95	771.49	919.81	541.78	932.23	694.53
2028	1384.89	787.09	1325.72	729.3	947.54	496.73	1130.74	796.8
2029	1478.92	788.15	1226.37	827.59	1017.43	638.42	1171.28	829.04
2030	1451.47	1265.04	1453.23	1059.21	1340.97	1014.56	1469.64	1196.59
2031	1510.11	1051.11	1501.86	907.38	1081.83	678.33	1225.85	1027.95
2032	1358.45	1133.04	1280.74	1091.36	1310.96	775.7	1260.29	1150.44

Year	Sub-Basin							
	k	I	E	F	H	M	C N d	A
2033	1397.78	1077.11	1354.88	988.03	1173.27	802.71	1274.88	1040.98
2034	1326.43	953.96	1177.57	891.65	1056.22	720.2	1187.47	905.05
2035	1579.63	1089.26	1626.5	950.32	1166.13	761.17	1244.91	1059.52
2036	1294.07	974.44	1276.31	881.79	1030.38	834.51	1104.86	926.25
2037	1274.38	986.61	1267.96	877.06	1080.75	768.16	1203.68	1009.04
2038	1461.19	991.62	1325.03	997.65	1276.99	1012.38	1387.77	1027.53
2039	1437.55	1037.08	1364.56	844.28	1049.52	600.55	1129.34	962.48
2040	1141.67	831.72	1155.66	817.15	1133.39	764.68	1227.23	809.19
2041	1508.82	984.73	1423.49	875.76	1079.92	925.83	1195.43	991.92
2042	1569.55	920.09	1398.86	1029.76	1244.32	828.51	1280.06	885.37
2043	1492.45	971.54	1433.73	947.17	1121.63	648.9	1258.67	840.14
2044	1429.77	815.11	1231.99	667.34	901.61	568.57	1072.36	763.98
2045	1303	739.86	1219.24	725.03	925.67	682.98	1063.77	718.32
2046	1180.29	831.14	1109.73	737.43	921.06	582.47	1052.52	792.51
2047	1353.58	914.55	1391.96	843.13	1144.72	588.21	1302.46	841.55
2048	1302.42	1071.61	1249.64	990.56	1063.19	959.83	1148.94	1017.03
2049	1517.56	910.37	1261.99	862.92	991.96	709.38	1239.1	904.05
2050	1421.83	913.04	1261.5	947.06	1159.23	692.25	1247.83	803.99
2051	1266.24	1037.99	1155.36	872.56	1002.55	754.84	1119.91	881.57
2052	1191.28	736.26	1129.94	735.13	944.31	578.35	1039.06	687.56
2053	1193.49	1006.48	1211.3	878.28	1146.89	848.31	1255.43	1038.38
2054	1289.82	1391.06	1344.2	1131.43	1150.28	1147.54	1172.57	1300.34
2055	1465.56	829.17	1337.13	861.1	1060.77	669.47	1106.92	775.39
2056	1263.92	776.65	1023.58	707.43	1057.65	621.78	1263.66	734.55
2057	1228.98	826.74	1116.43	790.64	1027.93	588.68	1202.8	842.87
2058	1218.63	998.68	1244.5	976.62	1145.4	912.12	1367.64	1035.73
2059	1054.15	979.3	1046.87	740.07	858.67	711.24	1001.65	1047.23
2060	1360.3	1015.79	1488.29	925.06	1189.2	670.19	1356.86	1020.1

Year	Sub-Basin							
	k	I	E	F	H	M	C N d	A
2061	1550.95	924.39	1430.06	894.37	1181.28	755.69	1355.54	883.2
2062	1055.76	734.92	1005.56	649.78	847.56	606.6	985.83	781.71
2063	1387.82	883.79	1281.58	888.23	1067.45	660.33	1129.12	855.91
2064	1173.12	730.72	1037.21	755.69	887.14	578.54	969.4	682.1
2065	1313.54	930.67	1329.24	911.22	1015.32	760.22	1121.67	1012.99
2066	1526.89	1003.03	1336.72	950.15	1215.85	676.81	1451.12	987.08
2067	1437.9	1104.91	1384.44	1095.03	1183.35	687.31	1294.01	994.45
2068	1183.34	830.31	1126.17	758.74	887.52	654.59	979.75	785.35
2069	1231.57	665.27	1063.89	699.71	962.65	523.12	1068.19	568.03
2070	1397.98	1095.44	1287.61	1022.13	1154.91	903.46	1182.64	1157.49
2071	1132.38	903.99	1076.8	772.98	966.18	661	1005.34	851.77
2072	1373.28	839.72	1237.41	831.89	1067.93	593.09	1199.76	773.34
2073	1342.47	1019.68	1258.64	1036.32	1337.02	842.38	1493.49	1001.28
2074	1491.97	1162.47	1447.51	1129.23	1309.79	918.35	1331.18	1207.9
2075	1183.71	908.37	1126.51	777.75	938.72	646.95	1026.68	808.53
2076	1619.96	1065.14	1544.65	1123.57	1382.12	916.04	1464.44	1007.93
2077	1163.2	794.05	1065.99	786.9	929.98	570.77	988.47	774.67
2078	1228.17	642.22	1196.09	660.03	870.89	496.89	937.96	605.83
2079	1510.91	868.17	1451.73	860.45	1052.9	634.17	1259.87	816.4
2080	1240.07	759.63	1133.32	720.93	911.68	526.01	1070.24	753.22
2081	1277.07	883.02	1132.93	832	996.25	603.22	1079.79	895.51
2082	1274.9	707.03	1130.37	826.92	1096.1	765.52	1198.12	690.68
2083	1494.32	897.48	1360.02	908.96	1236.98	783.42	1329.6	977.05
2084	1100.44	642.47	970.15	650.56	775.76	454.05	943.47	603.8
2085	1724.35	939	1477.53	1005.39	1268.13	668.76	1401.49	837.01
2086	1209.4	929.15	1132.11	828.2	977.6	712.71	1142.89	854.82
2087	1174.06	989.4	1201.78	911.18	1060.17	675.08	1061.38	918.16
2088	1134.54	916.68	1177.08	782.15	986.7	596.84	1134.75	968.27

Year	Sub-Basin							
	k	I	E	F	H	M	C N d	A
2089	1311.49	869.64	1236.11	850.19	1026.14	602.17	1123.22	821.52
2090	1479.86	1082.69	1454.42	1063.06	1254.52	921.56	1330.29	1090.33
2091	1695.54	1110.32	1717.75	1176.62	1402.65	1001.72	1484.78	1090.3
2092	1368.69	986.79	1383.61	953.34	1037.91	707.04	1169.78	850.24
2093	841.68	666.05	798.33	635.94	795.52	473.96	817.18	741.1
2094	1266.32	868.85	1160.67	822.15	1049.18	700.81	1218.18	904.5
2095	1440	909.23	1206.78	785.53	990.28	760.86	1221.17	925.23
2096	1260.23	981.85	1216.05	837.48	965.35	752.94	1069.71	946.55
2097	1198.13	852.84	1245.05	763.81	915.55	644.87	1041.34	808.17
2098	1226.85	680.52	1163.83	726.64	944.1	555.84	1036.15	611.43
2099	904.01	645.02	795.07	500.99	605.92	420.08	747.62	510.25
2100	1516.76	1072.62	1451.5	934.83	1205.49	771.46	1427.11	1005.93

Appendix 3: Climate Data Source, Projected Rainfall, RCP 8.5, Source (SMHI, 2016)

1. Appendix 3$_{A}$: Projected Rainfall Data, RCP 8.5

Years	Sub-Basin							
	F 1	H	K	I and E	C1	M	A	G
1951	874.51	1522.55	1564.16	1558.57	1495.44	1337.5	1346.56	1587.24
1952	960.22	1393.17	1441.15	1433.74	1411.27	1451.4	1288.59	1381.41
1953	605.38	1269.84	1213.23	1251.82	1216.75	1353.29	1303.75	1252.61
1954	707.45	1118.47	1143.73	1158.4	1031.8	1287.79	1129.35	1057.18
1955	556.66	1153.89	1270.83	1221.78	1100.83	1363.28	1344.77	1145.41
1956	804.19	1506.22	1256.78	1265.18	1218.85	1256.57	1182.36	1439.93
1957	725.92	1332.66	1374.03	1390.54	1332.52	1456.6	1313.02	1294
1958	763.94	966.92	1046.82	979.67	961.04	1171.42	1097.29	941.27

Years	Sub-Basin							
	F 1	H	K	I and E	C1	M	A	G
1959	1015.49	1663.08	1629.25	1720.06	1643.7	1580.04	1469.83	1648.57
1960	677.54	1149.37	1135	1134.74	1045.24	1167.1	1109.24	1122.23
1961	773.18	1241.53	1190.83	1246.22	1273.88	1231.21	1200.76	1233.96
1962	707.94	1363.32	1313.46	1342.65	1201.06	1220.78	1340.77	1325.78
1963	664.75	1278.16	1442.37	1455.89	1316.51	1448.46	1271.74	1268.64
1964	522.26	1390.25	1259.69	1345.19	1266.47	1367.23	1265.3	1389.14
1965	865.76	1143.61	1288.92	1211.26	1216.93	1330.24	1245.29	1100.42
1966	745.8	1181.93	1255.81	1205.86	1133.38	1355.17	1299.31	1082.22
1967	674.25	995.03	1030	1019.91	1005.74	1038.15	929.06	943.98
1968	682.34	1385.21	1270.24	1291.46	1281.61	1248.95	1130.94	1315.76
1969	696.92	1128.53	1265.52	1319.4	1337.65	1179.47	1048.12	1199.47
1970	760.24	1261.99	1138.87	1233.45	1274.09	1127.07	1157.25	1336.21
1971	540.7	1220.3	1272.76	1321.98	1316.62	1187.57	1133.21	1203.55
1972	651.21	906.69	1055.39	1045.28	1029.88	1210.58	1102.41	904.04
1973	750.63	1552.07	1527.17	1512.57	1452.93	1643.38	1402.47	1527.34
1974	565.17	1289.87	1215.44	1238.12	1177.93	1245.28	1153.91	1221
1975	700.91	1195.31	1108.04	1152.83	1170.28	1158.91	1107.68	1174.12
1976	969.76	1526.63	1133.58	1274.41	1265.36	1122.8	1186.77	1523.92
1977	643.44	1391.34	1253.85	1330.53	1294.61	1315.82	1215.03	1352.56
1978	789.26	1278.48	1266.56	1252.45	1229.93	1364.96	1312.87	1262.47
1979	477.34	1155.47	1140.22	1183.98	1156.96	1180.95	1175.29	1226.86
1980	818.82	1364.21	1378.62	1366.35	1322.27	1430.87	1387.86	1320.72
1981	836.01	1207.37	1292.13	1288.26	1192.69	1262.46	1182.71	1145.51
1982	688.31	985.68	1000.38	1003.17	1068.58	1048.63	951.52	1025.12
1983	484.98	1090.13	1241.49	1248.87	1245.59	1313.32	1224.8	1022.82
1984	606.72	1478.55	1374.12	1401.07	1321.86	1165	1245.41	1410.79
1985	560.23	1283.1	1273.08	1292.08	1195.71	1333.37	1196.8	1290.99

Years	Sub-Basin							
	F 1	H	K	I and E	C1	M	A	G
1986	889.48	1444.94	1450.75	1446.3	1402.89	1333.38	1197.19	1429.18
1987	693.16	1316.61	1335.38	1341.61	1289.44	1448.91	1364.26	1385.74
1988	611.99	1058.93	1199.84	1100.49	1023.62	1221.22	1136.13	1064.26
1989	603.98	1237.29	1207.09	1224.04	1227.45	1233.22	1087.21	1277.27
1990	794.7	1441.53	1573.71	1591.67	1616.05	1576.1	1467.05	1441.94
1991	751.6	1265.25	1365.2	1336.58	1267.43	1345.15	1225.23	1210.78
1992	630.14	1164.61	1269.84	1244.83	1091.27	1362.74	1235.02	1160.14
1993	625.35	1115.03	1066.8	1038.02	1018.27	973.82	928.41	1085.32
1994	728.67	1256.32	1227.42	1185.05	1181.47	1233.31	1121.82	1256.95
1995	709.46	817.29	844.78	775.75	764.34	1026.42	905.27	845.59
1996	709.23	1419.85	1231.83	1274.53	1313.2	1298.34	1227.68	1481.38
1997	623.12	1299.56	1252.62	1270.89	1284.07	1354.53	1243.28	1218.89
1998	840.06	1103.28	1122.21	1150.68	1164.51	1133.04	980.17	1123.31
1999	671.42	1223.41	1252.73	1206.11	1206.97	1435.43	1252.95	1277.52
2000	680.47	1344.4	1242.94	1298.6	1280.35	1395.58	1249.35	1319.7
2001	747.18	1415.79	1420.35	1495.75	1464.77	1395.95	1342.28	1321.28
2002	746.98	1065.7	1066.91	1114.62	1125.32	1097.03	1177.3	1144.45
2003	658.64	1149.73	1179.42	1165.86	1038.85	1318.38	1257.84	1068.7
2004	802.47	1129.77	1232.49	1134.95	1111.32	1324.77	1204.24	1065.01
2005	807.9	1583.24	1658.46	1677.32	1633.69	1610.47	1438.49	1524.51
2006	601.76	1240.42	1138.34	1162.51	1193.05	1172.68	1001.31	1157.07
2007	971.74	1380.31	1531.33	1511.93	1518.98	1545.53	1305.7	1377.44
2008	616.95	1047.03	1247.68	1203.91	1174.17	1275.51	1186.35	1045.82
2009	909.53	1382.59	1697.64	1598.18	1486.12	1751.41	1580.18	1303.78
2010	741.63	1247.95	1181.83	1152.8	1100.27	1216.82	1048.06	1240.2
2011	634.62	878.12	1128.69	1100.01	1096.58	1266.4	1107.19	905.03
2012	708.96	1079.47	1295.35	1198.46	1179.15	1336.93	1174.59	1040.23

Years	Sub-Basin							
	F 1	H	K	I and E	C1	M	A	G
2013	703.44	1199.85	1171.73	1222.97	1227.95	1166.26	1211.05	1309.77
2014	829.51	1188.82	1202.78	1217.06	1145.29	1179.31	1167.56	1210.52
2015	758.67	1303.64	1297.03	1332.85	1246.75	1400.72	1295.03	1186.93
2016	741.76	1043.52	1172.43	1129.99	1213.53	1209.13	1048.21	1019.58
2017	676.71	1322.69	1230.05	1286.97	1242.14	1242.55	1151.77	1335.2
2018	611.19	1138.07	1324.71	1283.51	1138.85	1367.94	1253.8	1103.63
2019	628.94	1132.95	1043.76	1079.17	1057.81	1184.8	1043.15	1073.89
2020	770.6	1173.99	1201.75	1199.76	1255.55	1330.03	1109.31	1222.49
2021	726.28	1352.22	1354.05	1407.25	1283.83	1304.31	1247.64	1304.58
2022	746.26	1256.12	1308.13	1299.28	1285.8	1383.3	1251.1	1350.23
2023	691.08	1215.53	1211.14	1155.73	1146.05	1410.61	1148.49	1212.26
2024	621.59	1254.5	1251.7	1307.44	1187.33	1290.54	1225.88	1271.74
2025	664.48	952.49	940.97	987.3	1015.98	1135.64	999.63	952.56
2026	772.96	992.79	1066.28	1034.91	1050.33	1173.79	1078.11	1006.22
2027	712.34	1022.45	1155.58	1082.91	977.97	1270.67	1100.25	928.92
2028	651.15	1394.84	1399.98	1422.54	1294.61	1661.95	1467.33	1296.12
2029	669.61	1182.41	1298.12	1352.13	1386.77	1407.81	1189.69	1272.55
2030	716.8	1262.42	1408.95	1390.67	1338.12	1346.58	1270.31	1193.67
2031	1057.99	1327.7	1313.47	1325.44	1251.02	1420.94	1347.61	1362.94
2032	817.34	1362.53	1316.23	1366.99	1373.53	1377.91	1272.43	1478.03
2033	591.84	1148.27	1279.38	1273.68	1149.05	1503.83	1325.7	1077.69
2034	777.25	1020.3	1039.58	1035.08	1080.04	1092.98	1007.95	1017.75
2035	667.59	1294.32	1229.17	1301.9	1261.56	1198.93	1105.63	1228.3
2036	591.15	1274.06	1279.65	1234.02	1164.76	1430.73	1236.7	1223.02
2037	823.36	1385.05	1316.03	1371.11	1347.36	1325.42	1384.8	1449.72
2038	949.56	1295.87	1325.56	1275.6	1223.73	1346.45	1183.13	1279.57
2039	802.94	1399.57	1558.07	1514.5	1479.01	1515.13	1290.05	1413.35

Years	Sub-Basin							
	F 1	H	K	I and E	C1	M	A	G
2040	874.37	920.39	1142.2	1088.79	1047.78	1258.66	1083.05	979
2041	796.96	1252.77	1064.71	1147.27	960.16	1225.85	1025.89	1196.39
2042	650.1	1235.21	1262.15	1275.56	1204.61	1313.69	1267.74	1203.39
2043	862.46	1209.86	1156.25	1162.36	1115.42	1424.89	1266.93	1153.66
2044	740.24	1244.64	1178.67	1225.85	1246.18	1319.5	1265.17	1293.78
2045	625.75	1489.58	1261.18	1267.28	1186.31	1363.39	1308.48	1447.1
2046	768.31	1272.3	1203.63	1191.98	1186.62	1426.96	1148.86	1325.71
2047	656.88	1124.78	1119.07	1105.83	1113.87	1295.44	1170.59	1105.72
2048	832.83	1285.45	1138.07	1155.97	1054.57	1216.77	1072.58	1229.72
2049	721.86	1332.9	1261.08	1326.34	1353.32	1305.14	1103.31	1330.63
2050	848.41	1585.14	1512.83	1612.74	1637.48	1455.48	1400.19	1647.76
2051	745.92	1343.81	1208.29	1282.89	1293.73	1246.24	1164.17	1370.2
2052	639.61	1068.33	1181.97	1159.67	1138.46	1203.15	1072.15	1078.98
2053	894.46	1475.13	1490.08	1490.34	1502.61	1304.41	1239.04	1548.57
2054	722.02	1492.86	1513.2	1523.49	1381.63	1413.52	1489.81	1356.89
2055	976.09	1482.93	1481.85	1552.31	1605.66	1486.06	1268.07	1582.27
2056	509.04	765.39	814.72	742.78	705.63	991.34	864.39	766
2057	671.78	1125.7	1122.06	1113	1088.8	1311.01	1257.08	1094.23
2058	622.09	1174.9	1099.62	1120.86	1106.31	1190.22	1089.81	1117.62
2059	628.69	1011.75	1256.24	1171.94	1073.47	1408.46	1116.08	949.27
2060	706.88	1441.64	1283.39	1330.32	1411.55	1343.66	1141.95	1477.61
2061	633.55	1314.99	1399.85	1390.75	1406.75	1368.25	1333.92	1341.37
2062	609.95	1145.34	1317.94	1213.17	1138.1	1228.13	1217.76	1150.64
2063	504.56	791.98	1092.08	965.72	866.61	1318.52	1157.36	732.16
2064	576.79	1423.74	1308.07	1306.15	1317.92	1389.03	1306.02	1498.07
2065	873.1	1348.49	1140.68	1254.54	1249.81	1171.26	1136.16	1414.06
2066	612.14	1141.29	1008.69	1037.85	1036.61	1178.77	1051.11	1187.88

	Sub-Basin							
Years	F 1	H	K	I and E	C1	M	A	G
2067	669.45	953.83	1013.43	982.83	949.68	1118.48	957.32	1046.06
2068	599.35	1115.49	1122.74	1162.11	1175.5	1178.89	1001.43	1081.82
2069	775.58	1309.05	1351.71	1302.78	1278.34	1427.36	1217.9	1315.23
2070	686.74	1094.24	1150.91	1151.58	1143.65	1223.95	1068.73	1259.56
2071	541.61	1486.68	1392.92	1417.27	1342	1469.36	1300.41	1515.24
2072	767.85	939.33	1004.15	979.05	958.66	1142.04	981.07	953.52
2073	705.9	1519.95	1341.16	1397.76	1367.42	1501.03	1284.52	1486.71
2074	849.67	1197	1259.25	1267.99	1304.61	1321.11	1153.51	1188.31
2075	650.31	1032.51	1040.15	1075.65	1070.45	1021.67	1002.18	1033.21
2076	685.37	1346.33	1272.09	1412.15	1235.05	1389.77	1279.28	1250.32
2077	641.6	1407.25	1356.22	1321.25	1314.94	1330.91	1293.41	1467.16
2078	747.5	1495.77	1384.09	1448.25	1398.49	1324.66	1262.89	1493.06
2079	604.26	1423.48	1398.16	1407.61	1406.8	1630.16	1320.75	1451.43
2080	427.08	1153.37	1164.4	1129.03	1073.12	1195.83	991.91	1071.59
2081	827.45	1136.74	1237.57	1192.36	1195.47	1237.26	1247.39	1112.63
2082	628.13	1194.64	1088.7	1123.68	1055	1235.4	1152.53	1165.18
2083	610.05	936.51	972.56	966.62	1047.94	1023.81	1042.23	945.42
2084	611.02	994.65	1123.45	1099.8	1032.61	1380.74	1211.4	989.65
2085	867.97	1418.51	1450	1437.08	1494.7	1368.57	1233.8	1407.52
2086	504.85	918.68	965.45	878.02	859.57	1340.62	1112.66	854.21
2087	638.85	1048.41	1036.09	1030.86	1027.55	1214.67	1056.03	1060.3
2088	808.03	1012.13	1047.81	1005.21	1022.02	1118.56	1021.58	1011.86
2089	796.19	1117.65	1049.46	1042.1	1057.32	1272.66	1037.97	1089.12
2090	736	1128.63	1132.91	1196.52	1192.66	1400.29	1143.48	1117.67
2091	900.56	1446.03	1456.67	1473.37	1485.13	1550.62	1394.91	1509.98
2092	1074.1	1665.13	1677.5	1705.67	1729.92	1719.95	1491.65	1726.43
2093	791.4	1050.58	1045.71	1040.76	1074.81	1280.34	1040.57	1090.71

Years	Sub-Basin							
	F 1	H	K	I and E	C1	M	A	G
2094	736.74	1397.39	1305.63	1273.21	1267.74	1398.49	1259.03	1379.18
2095	731.88	1099.2	1265.12	1160.44	1210.74	1443.37	1229.75	1108.4
2096	570.15	1048.42	1039.24	999.71	975.01	1200.07	1115.16	1024.25
2097	191.72	448.39	471.24	453.01	435.02	594.01	523.05	445.7

2. Appendix 3_B: Projected Rainfall Data, RCP 8.5

Years	Sub-Basin							
	C and D	F	I	O	S	L 1	N1	F 5
1951	1434.13	1585.53	1314.51	1254.42	829	1087.92	1236.91	989.14
1952	1326.62	1409.72	1253.75	1226.46	848.97	1187.06	1221.89	1101.93
1953	1260.98	1333.28	974.66	1016.17	633.66	714.95	994.45	691.51
1954	1192.38	1130.14	918.64	1174.58	569.85	714.8	1072.76	733.02
1955	1238.48	1185.98	983.16	1053.93	561.96	709.24	1058.41	704.86
1956	1250.35	1347.48	1137.07	1150.69	834.99	996.67	1151.03	973.5
1957	1404.57	1407.58	1182.62	1141.34	751.66	878.59	1199.93	827.56
1958	999.97	982.74	871.78	906.92	581.44	757.92	882.66	698.91
1959	1556.59	1725.28	1429.81	1407.48	957.97	1105.81	1432.85	1043.9
1960	1118.56	1139.72	846.1	974.2	542.7	746.57	881.38	771.14
1961	1247.97	1252.73	1183.04	1184.34	798.41	1039.93	1208.81	1121.78
1962	1408.16	1346.99	1064.52	1046.83	666.95	970.4	1066.31	912.29
1963	1365.54	1416.72	1179.64	1230.66	569.22	957.4	1215.91	968.82
1964	1275.78	1399.44	1055.64	1066.9	560.66	917.89	1032.27	831.13
1965	1162.29	1174.41	1117.11	1202.05	810.57	898.64	1157.44	849.82

Years	Sub-Basin							
	C and D	F	I	O	S	L 1	N1	F 5
1966	1191.01	1215	1108.64	1125.19	682.5	841.15	1147.03	867.87
1967	950.66	1043.46	929.43	882.78	536.76	791.14	924.08	747.13
1968	1141.98	1386.68	1104.49	1047.9	754.57	840.05	1128.74	817.63
1969	1207.87	1279.55	1158.91	951.77	707.29	905.23	1018.3	890.04
1970	1211.55	1331.07	1095.95	935.55	773.31	961.89	955.15	938.12
1971	1259.05	1308.28	1210.32	1094.66	733.18	1096.9	1050.61	942.06
1972	1068.45	1053.71	946.25	923.21	478.48	669.17	895.95	601.87
1973	1419.42	1513.01	1263.33	1490.95	657.94	1103.18	1422.39	1051.47
1974	1206.44	1277.58	1042.81	1122.72	646.77	1030.37	1120.01	950.38
1975	1129.77	1238.34	1033.72	1031.7	549.99	844.4	1078.8	797.72
1976	1235.36	1425.42	1124.19	1131.98	870.07	997.62	1087.46	1022.7
1977	1294	1383.65	1060.78	1114.96	640	852.88	1044.83	872.17
1978	1274.22	1301.05	1110.19	1101.54	675.13	925.48	1048.25	910.69
1979	1190.97	1244.11	967.26	985.56	423.71	752.66	964.93	679.15
1980	1345.64	1379.52	1187.21	1351.23	874.31	877.04	1320.23	861.61
1981	1279.83	1277.43	1047.63	1277.55	872.41	1053.41	1145.41	980.61
1982	940.94	1040.25	965.74	967.9	612.49	743.06	939.05	713.15
1983	1174.83	1259.65	1019.16	1299.5	579.94	617.1	1240.59	606.81
1984	1402.48	1485.63	1184.73	1124.97	655.72	1002.27	1167.79	974.45
1985	1266.99	1342.75	1111.26	1192.64	636.17	900.76	1129.28	854.72
1986	1313.41	1436.26	1347.14	1470.86	1025.19	1043.92	1358.4	1029.12
1987	1398.71	1380.47	1220.23	1240.58	894.63	1126.18	1295.67	1107.2
1988	1099.26	1119.24	958.12	1127.69	608.39	665.66	1163.7	627.33
1989	1183.37	1281.19	1063.98	1121.99	629.9	938.94	1066.52	827.44
1990	1508.89	1592.48	1426.44	1407.84	728.8	1003.61	1450.05	960.65
1991	1262.29	1334.99	1215.01	1155.29	667.28	974.74	1220.01	930.93
1992	1329.91	1201.31	968.31	1141.46	602.08	774.08	1086.61	742.18

Years	Sub-Basin							
	C and D	F	I	O	S	L 1	N1	F 5
1993	1010.75	1070.61	890.88	865.2	591.36	860.31	939.25	805.15
1994	1159.18	1211.7	1083.19	1178	601.27	779.72	1134.99	692.54
1995	795.53	794	735.58	1014.62	618.89	637.39	897.75	630.38
1996	1274.28	1381.16	1204.56	1175.92	602.27	1060.92	1119.08	937.97
1997	1206.04	1301.93	1077.2	1142.81	679.3	703.51	1089.47	696.33
1998	996.99	1156.08	1102.64	1063.01	794.54	1091.77	1078.86	1032.22
1999	1163.4	1204.64	1126.1	1179.1	627.48	838.22	1154.1	836.25
2000	1241.53	1368.4	1091.72	1272.66	781.48	881.14	1191.24	834.48
2001	1409.2	1501.05	1360.32	1435.12	880.29	1049.67	1415.23	1037.52
2002	1104.95	1124.1	961.58	800.16	577.39	1024.89	738.43	1100.93
2003	1207.47	1179.68	935.2	983.71	720.93	877.41	946.63	807.1
2004	1121.8	1148.06	1052.77	1123.02	797.53	867.88	1068.97	882.41
2005	1553.51	1677.01	1473.71	1464.24	1103.33	1362.78	1444.75	1318.19
2006	1090.22	1236.12	1031.47	959.8	604.47	933.06	981.52	941.59
2007	1344.18	1484.31	1366.07	1416.46	919.08	1049.25	1381.36	950.06
2008	1186.69	1135.24	1078.65	968.4	540.11	908.36	1038.3	854.96
2009	1577.92	1481.89	1395.84	1592.62	865.69	895.13	1571.7	841.41
2010	1093.95	1225.13	1061.58	1139.67	591.52	913.21	1115.23	865.69
2011	1091.83	989.35	1063.67	998.17	636.99	688.96	1015.17	630.02
2012	1172.32	1136.65	1093.35	1177.15	746.35	778.83	1142.11	755.11
2013	1179.65	1254.14	1140.63	1215.45	781.14	1136.38	1259.24	1085.13
2014	1192.11	1262.59	1088.35	1005.78	866.75	1033.53	1026.41	1018.33
2015	1244	1356.89	963.08	1066.43	608.4	766.63	1030.22	693.46
2016	1048.12	1160.1	1039.77	1023.54	828.9	855.83	1035.46	738.15
2017	1219.19	1332.01	1076.07	1125.08	719.17	1001.63	1072.01	987.92
2018	1315.57	1208.8	943.24	1116.11	603.69	759.31	1088.64	710.15
2019	1085.3	1116.58	905.2	1049	685.68	923.44	978.25	865.01

Years	Sub-Basin							
	C and D	F	I	O	S	L 1	N1	F 5
2020	1153.05	1209.29	1153.86	1178.16	747.25	1069.25	1158.27	1054
2021	1292.44	1425.21	1034.82	1054.58	683.27	779.84	1052.63	754.96
2022	1228.7	1374.59	1113.52	1140.76	780.98	859.8	1170.46	879.56
2023	1118.75	1176.64	1027.17	1257.8	729.36	836.21	1189.46	810.62
2024	1199.61	1272.56	1030.87	1167.58	581.1	775.24	1112.73	740.16
2025	948.4	963.73	882.5	910.53	572.5	666.34	875.02	657.65
2026	1021.26	1041.87	982.28	1046.28	760.76	796.47	1001.19	910.23
2027	1124.7	1096.28	888.22	1019.84	626.39	820.02	963.24	804.5
2028	1431.65	1459.12	1138.33	1317.16	688.43	897.82	1255.63	866.23
2029	1165.84	1350.17	1241.24	1236.39	735.08	885.4	1179.34	792.63
2030	1300.91	1329.47	1175.99	1254.46	736.17	960.76	1212.17	994.99
2031	1321.04	1377.66	1053.17	1360.05	707.8	961.35	1160.53	983.74
2032	1364.17	1379.51	1227.22	1198.23	749.39	953.52	1163.12	886.11
2033	1283.95	1297.17	986.81	1202.37	544.52	760.96	1205.96	722.67
2034	998.92	1037.81	995.79	1032.56	757.38	835.03	1010.4	851.26
2035	1172.87	1353.35	1108.73	1013.57	682.82	930.82	1078.51	856.08
2036	1152.31	1262.32	948.88	1081.41	580.61	764.06	1128.75	700.85
2037	1370.89	1435.6	1078.16	1136.37	688.92	1130.72	1088.42	988.47
2038	1211.89	1266.97	1203.06	1167.17	776.16	1107.19	1194.89	1049.18
2039	1406.41	1490.05	1352.89	1429.19	860.59	1122.19	1413.24	1129.17
2040	1067.79	1015.06	945.35	1027.92	757.32	913.34	1033.26	826.64
2041	1069.76	1207.83	887.79	1016.56	616.55	779.49	992.71	704.33
2042	1226.11	1322.41	1051.09	1191.09	661.45	758.99	1162.75	736.55
2043	1160.64	1261.27	976.9	1030.63	772.43	750.7	1000.83	750.45
2044	1197.31	1266.95	1126.03	1250.62	827.94	1021.12	1227.64	962.04
2045	1288.53	1466.79	1067.23	1204.54	668.55	893.04	1145.2	815.41
2046	1176.76	1243.28	1074.9	1104.09	726.38	989.9	1072.74	922.47

Years	Sub-Basin							
	C and D	F	I	O	S	L 1	N1	F 5
2047	1139.72	1142.44	1026.23	1047.49	647.86	835.77	998.89	844.1
2048	1118.59	1267.34	933.23	1004.62	603.36	774.66	1032.92	791.17
2049	1235.99	1344.16	1210.99	1117.46	872.09	1120.3	1139.92	1106.78
2050	1464.66	1679.16	1489.06	1295.37	866.39	1224.88	1301.75	1099.11
2051	1182.59	1348.82	1142.21	1164.69	942.05	1061.33	1152.79	1025.36
2052	1087.8	1140.25	1002.4	1001.07	560.06	731.96	1045.4	736.09
2053	1346.57	1494.39	1369.57	1253.03	1006.12	1186.99	1279.84	1104.35
2054	1448.33	1504.1	1215.29	1240.36	750.17	878.62	1268.23	815.26
2055	1377.26	1557.55	1415.79	1270.78	872.82	1203.7	1285.39	1190.35
2056	808.22	759.62	711.49	863.01	467.95	587.65	898.78	620.77
2057	1169.54	1146.9	976.46	1056.73	666.35	830.69	1046.28	810.67
2058	1069.62	1196.32	950.62	1076.17	771.01	750.42	1090.56	748.07
2059	1154.62	1095.68	1051.55	1249.77	677.16	772.41	1191.08	781.34
2060	1186.06	1407.31	1227.32	1113.45	730.05	997.4	1106.16	973.93
2061	1312.97	1353.84	1230.11	1217.95	691.93	950.78	1166.49	928.98
2062	1206.04	1164.89	1102.81	984.07	699.79	824.47	1052.13	750.08
2063	1006.02	889.83	809.09	1053.67	420.27	656.99	953.47	576.6
2064	1286.82	1388.22	1136.2	1136.72	664.89	990.82	1134.99	871.72
2065	1156.03	1363.26	1260.33	1157.11	834.67	1172.87	1207.19	1176.56
2066	1014.83	1102.76	1002.49	976.63	620.9	721.06	996.42	701.51
2067	939.94	975.32	889.83	942.39	658.35	848.74	938.19	860.16
2068	1036.04	1162.34	1025.93	998.64	590.06	712.22	981.46	696.38
2069	1276.6	1283.2	1271.05	1282.47	775.01	1035.67	1280.49	1049.05
2070	1071.01	1179.52	1015.38	1078.71	678.91	877.56	1041.52	831.61
2071	1352.33	1491.01	1096.69	1163.76	603.43	878.51	1133.12	821.67
2072	909.71	996.06	915.31	947.92	784.73	823.54	890.71	853.16
2073	1330.24	1496.98	1118.38	1021.1	653.58	886.54	1068.63	859.4

Years	Sub-Basin							
	C and D	F	I	O	S	L 1	N1	F 5
2074	1197.51	1254.28	1213.68	1150.59	827.84	929.35	1128.76	890.34
2075	982.89	1070.99	950.08	947.07	684.71	911.41	870.3	857.14
2076	1379.78	1395.6	1051.07	1044.43	684.62	829.14	979.65	821.47
2077	1281.8	1374.55	1246.38	1082.22	614.3	1064.5	1128.82	895.73
2078	1336.2	1513.05	1240.4	1154.88	722.38	955.9	1228.5	844.17
2079	1282.2	1452.19	1180.45	1273.92	546.02	870.21	1264.22	789.92
2080	1085.27	1205.61	940.69	1037.75	561.98	709.34	963.07	704.35
2081	1210.98	1208.44	1063.16	1108.86	840.1	782.7	1121.17	770.89
2082	1152.59	1167.65	883.56	992.3	515.16	620.81	943.21	599.53
2083	921.18	925.29	924.77	902.93	554.08	671.33	934.48	673.68
2084	1085.96	1084.53	936.53	973.61	627.74	736.49	917.79	693.85
2085	1336.27	1464.45	1276.33	1258.4	926.55	1070.71	1263.91	1023.28
2086	904.57	938	778.8	1039.14	591.84	687.44	914.13	652.93
2087	1028.29	1079.76	894.9	1072.94	687.87	858.4	991.53	845.72
2088	1007.49	1002.56	1026.63	953.38	792.92	894.21	988.78	1000.23
2089	1034.07	1119.23	980.32	1088.09	707.46	829.4	1033.96	867.75
2090	1162.61	1221.41	991.87	1005.06	648.17	701.73	976.6	642.38
2091	1382.68	1507.34	1304.13	1308.87	808.5	1045.36	1298.41	1013.79
2092	1536.11	1723.86	1556.66	1607.55	1161.94	1395.63	1530.3	1283.61
2093	1014.4	1101.12	956.89	1148.12	656.94	805.71	1074.48	869.25
2094	1234.45	1356.58	1174.95	1240.4	743.47	928.21	1226.09	899.07
2095	1094.91	1151.99	1154.46	1245.9	748.65	1027.17	1252.98	983
2096	1092.86	1047.37	887.2	971.65	591.76	791.31	932.87	751.68
2097	472.43	475.87	360.43	384.51	180.97	234.47	373.49	207.4

3. Appendix 3C: Projected Rainfall Data, RCP 8.5

Year	Sub-Basin					
	R	F 3	F 4	Q	LK	P
1951	1106.45	867.88	880.59	990.94	862.92	1146.15
1952	1104.77	1068.51	1073.55	958.02	982.36	1254.29
1953	848.69	600.25	701.62	705.6	693.18	1070.64
1954	965.93	634.94	651.85	643.51	629.15	1224.98
1955	931.45	524.48	644.58	726.6	672.59	1057.01
1956	1064.97	979.56	942.52	934.72	834.71	1134.89
1957	1108.43	807.04	844.75	862.77	798.92	1047.36
1958	806.28	744.3	654.32	609.96	682.75	921.57
1959	1254.28	1063.95	1031.18	1026.52	853.84	1398.89
1960	793.78	845.71	780.19	660.81	752.04	1035.84
1961	1182.57	826.8	968.23	971.12	1005.57	1153.29
1962	989.38	822.37	850.1	830.05	879.62	1055.31
1963	1127.36	719.36	794.48	832.09	823.35	1195.12
1964	872.91	632.87	694.33	708.87	738.17	1061.87
1965	1127.78	865.25	876.53	921.18	719.33	1232.92
1966	1013.97	754.74	788.51	833.41	729.16	1080.15
1967	866.01	670.36	794.35	738.37	667.33	849.73
1968	1078.66	790.76	821.21	850.7	662.58	969.92
1969	1005.11	832.38	871.16	892.78	675.49	961.72
1970	953.95	869.52	922.48	938.55	873.88	949.69
1971	1070.17	648.94	810.03	897.34	643.8	1080.65
1972	790.58	608.49	568.85	683.92	582.12	964.66
1973	1226.4	859.89	926.16	982.04	861.07	1426.48
1974	1061.86	650.32	839.26	877.11	766.02	1057.27
1975	964.98	652.93	661.31	756.48	723.7	928.39
1976	1027.78	1048.34	983.77	955.63	972.33	1123.6

Year	Sub-Basin					
	R	F 3	F 4	Q	LK	P
1977	958.54	750.08	843.78	749.76	806.05	1104.9
1978	915.71	790.34	775.18	705.31	874.54	1048.08
1979	843.32	563.24	611.69	653.92	656.72	970.38
1980	1137.21	924.72	856.01	901.27	770.98	1310.6
1981	1098.96	928.89	989.32	998.38	813.14	1324.77
1982	828.47	702.95	730.52	739.03	748.87	1020.18
1983	1034.19	599.77	598.43	693.27	596.02	1240.82
1984	1085.34	739.57	866.78	888.56	799.62	1137.31
1985	1005.97	713.29	752.83	900.9	684.7	1132
1986	1294.28	1032.15	1074.31	1175.35	809.69	1406.03
1987	1263.77	827.02	1012.05	1089.83	811.41	1228.17
1988	1006.75	622.85	609.78	694.8	583.54	1082.57
1989	1020.08	748.21	703.75	903.92	631.26	1117.25
1990	1270.68	798.33	853.3	939.77	756.03	1344.27
1991	1018.01	868.43	917.82	926.75	925.49	1060.46
1992	981.6	678.45	691.41	744.74	728.23	1139.1
1993	804.71	766.84	803	731.17	706.62	832.61
1994	969.21	660.93	633.17	725.19	612.77	1167.5
1995	839.42	701.26	641.95	628.34	669.25	954.85
1996	1047.58	862.93	825.76	845.61	836.46	1157.28
1997	957.81	689	717.49	800.11	639.47	1153.81
1998	1056.71	840.95	938.39	967.03	734.28	1070.7
1999	1026.51	687.61	799.54	797.83	765.9	1183.21
2000	1149.47	699.93	792.43	959.98	727	1192.33
2001	1364.65	1008.21	1056.64	1083.28	919.63	1392.94
2002	695.94	774.93	900.26	763.38	870.16	897.14
2003	902.85	757.19	790.74	779.66	775.82	1002.01

Year	Sub-Basin					
	R	F 3	F 4	Q	LK	P
2004	1047.81	872	902.86	912.39	782.46	1163.04
2005	1355.51	1034.83	1262.21	1240.66	1164.09	1380.5
2006	874.81	738.12	832.86	800.48	742.64	913.66
2007	1263.77	925.7	901.41	1010.68	881.63	1376.49
2008	882.61	699.4	726.83	761.5	756.95	933.57
2009	1388.75	867.46	843.4	1091.34	774.17	1545.25
2010	1005.21	743.46	741.19	840.51	767.5	1035.25
2011	954.06	699.01	577.25	674.63	554.21	991.06
2012	1087.8	737.89	728.11	880.57	618.78	1144.43
2013	1140.9	850.7	987.87	1034.33	941.34	1110.54
2014	947.5	867.89	954.29	920.52	835.93	996.21
2015	953.26	811.31	775.79	789.58	696.61	1070.84
2016	951.05	837.9	786.34	868.29	700.24	1022.18
2017	996.26	801.78	872.19	822.67	900.9	1097
2018	912.22	616.45	652.1	705.2	614.72	1072.32
2019	900.48	752.59	808.48	789.75	808.35	1027.83
2020	1064.52	834	995.35	965.45	817.06	1148.59
2021	920.55	767.95	765.99	836.46	612.52	1071
2022	1121.58	849.23	815.6	919.72	779.64	1154.51
2023	1113.26	739.83	775.31	861.77	741.56	1179.22
2024	1010.59	696.88	708.53	779.22	629.45	1076.04
2025	803.23	715.31	648.15	623.37	676.7	928.05
2026	901.52	884.36	868.77	776.24	741.38	1011.85
2027	878.53	675.22	722.59	756.29	707.38	1032.19
2028	1104.47	738.45	763.99	799.21	709.82	1307.98
2029	1097.16	752.83	716.41	848.91	722.26	1199.43
2030	1143.94	820.08	866.74	951.1	800.39	1154.91

Year	Sub-Basin					
	R	F 3	F 4	Q	LK	P
2031	1116.9	1003.27	946.66	852.63	888.91	1440.57
2032	1101.98	869.7	894.06	933.6	742.47	1175.99
2033	989.26	683.08	660.24	750.92	574.03	1174.78
2034	947.14	839.32	871.89	824.8	779.9	992.46
2035	965.58	775.78	810.11	806.8	795.94	937.23
2036	1023.49	678.57	621.87	749.69	735.97	1071.25
2037	892.83	806.89	810.72	807.52	920.55	1128.93
2038	1086.89	980	955.66	987.03	918.15	1125.88
2039	1296.35	941.21	1042.26	1083.15	979.61	1411.12
2040	966.06	817.68	820.32	857.32	745.55	993.42
2041	962.05	661.94	628.12	741.25	627.36	1023.21
2042	995.43	705.73	740.02	753.94	717.38	1163.3
2043	929.9	845.49	764.79	727.27	748.71	1022.97
2044	1153.08	858.33	902.55	917.09	763.01	1261.85
2045	1007.62	657.86	760.41	828.33	687.18	1164.04
2046	985.16	1006.55	926.08	908.38	805.75	1102.29
2047	929.49	749.37	811.06	770.12	733.42	1070.88
2048	905.33	797.63	729.47	701.92	752.6	1000.7
2049	1137.17	865.23	1035.73	954.99	916.89	1116.34
2050	1223.91	980.61	939.2	1105.27	924.46	1239.34
2051	1138.62	904.85	1001.67	994.05	871.62	1206.62
2052	901.96	711.48	698.92	756.92	762.52	853.09
2053	1252.32	1070.51	1043.48	1074.89	1008.92	1185.99
2054	1148.9	825.75	781.64	899.77	698.06	1168.66
2055	1200.09	1049.98	1039.3	1040.83	939.42	1266.71
2056	846.12	616.48	712.2	696.45	639.15	764.49
2057	958.17	778.06	764.53	754.84	723.54	1002.87

Year	Sub-Basin					
	R	F 3	F 4	Q	LK	P
2058	1003.8	696.34	779.72	847.71	607.66	1016.35
2059	1087.68	678.4	750.33	778.66	664.7	1241.05
2060	1040.88	854.23	881.8	891.78	912.71	1076.48
2061	1011.86	800.09	855.86	855.99	777.73	1188.14
2062	972.33	775.31	781.77	901.57	694.14	944.32
2063	779	507.33	560.06	593.59	554.25	986.43
2064	1024.51	597.67	704.31	829.24	792.9	1010.59
2065	1101.14	993.39	1075.82	988.86	962.71	1055.79
2066	926.6	662.44	645.65	726.86	713.19	912.82
2067	855.44	652.9	747.43	731.78	886.55	925.78
2068	876.7	734.08	719.98	696.35	612.81	960.77
2069	1176.02	997.23	1042.13	999.36	882.59	1253.95
2070	915.85	846.16	798.21	813.02	746.76	1016.14
2071	976.69	721.91	748.05	785.14	633.53	1112.17
2072	875.5	914.27	854.71	856.97	752.29	979.23
2073	918.44	758.6	764.3	757.57	708.73	983.07
2074	1089.32	881.12	923.64	999.4	887.31	1105.94
2075	859.25	736.67	738.89	811.77	632.86	997.28
2076	909.69	768.46	777.2	793.57	734.41	1012.92
2077	1066.98	818.15	898.34	898.76	774.47	1069.86
2078	1146.64	751.24	766.51	944.02	729.56	1055.79
2079	1154.62	629.6	653.04	776.99	753.34	1226.1
2080	812.91	664.1	697.87	677.83	659.34	1044.82
2081	1091.47	870.43	822.1	897.43	737.92	1096.6
2082	818.87	631.4	591.69	581.09	605.88	1030.04
2083	897.02	676.15	698.13	732.55	702.74	885.6
2084	886.25	705.69	679.02	669.73	594.39	988.96

Year	Sub-Basin					
	R	F 3	F 4	Q	LK	P
2085	1194.33	968.2	1037.45	1102.83	943.19	1238.18
2086	810.36	582.64	622.51	735.29	546.8	1072.12
2087	962.12	854.6	860.71	773.28	820.81	1092.47
2088	914.63	947.2	1039.38	862.48	973.06	901.6
2089	939.36	852.23	881.42	821.2	810.45	1058.91
2090	844.22	667.82	594.86	652.22	593.9	1045.6
2091	1191.97	882.02	978.32	1003.49	1007.62	1202.94
2092	1479.81	1278.22	1203.63	1282.9	1088.29	1616.07
2093	942.97	854.7	916.55	793.57	820.56	1101.28
2094	1147.65	764.73	808.7	984.77	760.83	1208.47
2095	1115.51	836.58	868.72	923.95	835.98	1236.49
2096	838.69	703.73	670.25	657.98	709.89	944.09
2097	326.33	203.81	196.89	236.41	177.33	395.76

Appendix 4: Global Climate Models, Projected Temperature, RCP 4.5, Source (SMHI, 2016)

1. Appendix 4A: Global Climate Models RCP 4.5

Zambia analysis RCP4.5				
Year	CNRM-CLMcom	CNRM-RCA4	EC-EARTH CLMcom	EC-EARTH RCA4
1951	22.3	22.5	22.2	22.4
1952	22.5	22.3	22.6	22.4
1953	22.2	22.0	21.9	21.7
1954	22.3	22.2	21.7	21.8
1955	22.4	22.3	21.9	22.2
1956	21.8	22.0	22.0	21.8

Zambia analysis RCP4.5				
Year	CNRM-CLMcom	CNRM-RCA4	EC-EARTH CLMcom	EC-EARTH RCA4
1957	22.3	22.3	21.9	22.3
1958	22.2	22.1	22.2	21.7
1959	22.3	22.1	22.0	22.3
1960	22.3	22.6	22.1	22.1
1961	22.0	22.2	22.4	22.5
1962	22.4	22.6	22.3	22.3
1963	22.3	22.0	21.6	21.6
1964	22.3	22.2	21.6	21.4
1965	22.7	22.5	21.8	21.9
1966	21.9	22.1	21.8	21.9
1967	22.1	22.3	22.1	21.8
1968	22.1	22.1	22.2	22.1
1969	22.0	21.8	21.9	22.1
1970	21.9	21.9	22.5	22.3
1971	22.3	22.8	22.1	22.0
1972	22.3	22.2	22.0	22.1
1973	22.5	22.3	21.7	22.0
1974	22.6	22.3	22.5	22.1
1975	22.2	22.3	22.1	22.0
1976	22.1	22.7	22.1	22.2
1977	22.1	22.6	22.6	22.2
1978	22.4	22.7	22.5	21.9
1979	21.8	22.3	22.3	22.2
1980	22.4	22.4	22.8	22.6
1981	23.2	22.7	22.6	22.0
1982	22.2	21.9	22.2	22.1
1983	22.1	22.0	22.2	22.1

Zambia analysis RCP4.5				
Year	CNRM-CLMcom	CNRM-RCA4	EC-EARTH CLMcom	EC-EARTH RCA4
1984	22.2	22.6	22.2	22.5
1985	22.2	22.3	22.5	22.3
1986	22.3	22.5	22.7	22.5
1987	22.7	22.6	22.5	22.0
1988	22.7	22.7	22.7	22.8
1989	22.6	22.5	22.5	22.5
1990	22.7	22.5	22.6	22.7
1991	22.2	21.8	22.8	22.6
1992	22.2	22.0	22.0	22.5
1993	22.1	22.2	22.6	22.2
1994	22.7	22.5	22.1	22.4
1995	22.7	22.8	22.9	22.4
1996	22.4	22.5	22.7	22.8
1997	22.6	22.5	22.7	22.9
1998	22.7	22.7	22.4	22.7
1999	22.6	22.2	22.7	22.6
2000	22.4	22.9	23.2	23.1
2001	23.0	23.2	22.4	22.6
2002	22.6	23.1	22.9	22.7
2003	22.8	22.8	22.7	22.7
2004	22.7	23.0	22.8	22.9
2005	23.0	22.7	22.5	22.7
2006	22.7	22.7	22.8	23.1
2007	22.8	22.9	22.9	22.9
2008	23.0	23.3	22.6	22.7
2009	23.4	22.8	22.5	22.9
2010	22.6	22.7	23.0	22.9

Zambia analysis RCP4.5				
Year	CNRM-CLMcom	CNRM-RCA4	EC-EARTH CLMcom	EC-EARTH RCA4
2011	22.6	23.0	22.7	23.0
2012	22.5	22.7	23.0	22.9
2013	22.7	23.1	23.1	23.0
2014	23.1	23.1	23.5	22.9
2015	23.0	22.9	22.9	22.6
2016	23.2	23.1	23.7	23.0
2017	23.1	23.4	23.5	23.2
2018	22.7	23.0	22.8	22.9
2019	23.3	23.0	23.3	23.3
2020	23.1	23.1	23.7	23.8
2021	23.0	22.9	23.6	23.2
2022	22.9	22.8	23.3	23.2
2023	22.8	22.9	23.7	23.9
2024	23.0	23.1	23.7	23.5
2025	23.6	23.5	23.2	23.6
2026	23.3	23.2	23.4	23.3
2027	23.0	23.1	23.5	23.2
2028	23.3	23.3	23.3	23.5
2029	23.3	23.1	23.6	23.6
2030	23.1	23.0	23.2	23.5
2031	23.4	23.4	22.8	23.1
2032	23.7	23.7	23.0	23.2
2033	23.4	22.9	23.1	23.3
2034	23.2	23.6	23.2	23.4
2035	23.6	23.8	23.5	23.7
2036	23.2	23.3	23.6	23.7
2037	23.3	23.3	23.3	23.5

Zambia analysis RCP4.5				
Year	CNRM-CLMcom	CNRM-RCA4	EC-EARTH CLMcom	EC-EARTH RCA4
2038	23.5	23.8	23.5	24.1
2039	23.8	23.8	23.7	24.0
2040	23.0	23.3	23.7	23.8
2041	23.8	23.8	23.7	23.8
2042	23.2	23.4	23.5	23.8
2043	23.5	23.6	23.6	23.7
2044	23.5	23.6	23.7	24.0
2045	23.8	23.4	24.5	24.1
2046	23.7	23.9	24.2	24.3
2047	24.7	24.7	23.8	23.8
2048	24.1	23.7	23.8	24.0
2049	23.8	23.7	23.9	24.5
2050	23.5	23.6	23.8	23.8
2051	23.7	23.8	24.1	24.1
2052	23.9	23.6	24.3	24.3
2053	24.0	24.2	23.7	23.7
2054	23.9	23.9	23.6	23.9
2055	24.0	24.1	23.7	24.1
2056	24.0	23.6	24.3	24.4
2057	23.8	23.9	24.1	24.4
2058	23.7	23.6	24.2	24.2
2059	23.8	23.9	24.2	24.1
2060	23.9	23.9	23.8	24.3
2061	24.0	23.8	23.8	24.5
2062	23.6	23.9	24.4	24.0
2063	24.1	24.0	23.9	24.1
2064	24.1	24.1	24.6	24.1

Zambia analysis RCP4.5				
Year	CNRM-CLMcom	CNRM-RCA4	EC-EARTH CLMcom	EC-EARTH RCA4
2065	24.5	24.0	24.3	24.7
2066	23.6	23.9	24.4	24.6
2067	24.2	24.1	24.3	24.6
2068	24.1	23.8	24.2	24.4
2069	24.4	24.3	24.4	24.0
2070	24.3	24.2	23.8	24.2
2071	24.1	24.6	24.1	24.4
2072	24.4	24.5	24.1	23.9
2073	24.3	24.4	24.2	24.4
2074	23.7	24.0	23.9	24.4
2075	24.4	24.5	24.8	24.7
2076	23.9	24.0	24.1	24.1
2077	24.7	24.2	24.2	24.7
2078	23.9	24.3	24.5	24.3
2079	24.2	24.0	24.3	24.6
2080	23.9	24.3	24.4	25.0
2081	25.0	24.6	24.6	24.6
2082	24.1	24.5	23.9	23.7
2083	24.9	24.8	23.8	24.5
2084	24.1	24.5	24.8	25.3
2085	24.2	24.6	24.6	25.0
2086	23.7	24.1	24.1	24.5
2087	24.8	24.5	24.0	24.2
2088	24.5	24.4	24.3	24.4
2089	24.7	24.2	24.3	24.5
2090	24.1	23.9	24.3	24.6
2091	24.7	24.7	23.8	24.4

Zambia analysis RCP4.5				
Year	CNRM-CLMcom	CNRM-RCA4	EC-EARTH CLMcom	EC-EARTH RCA4
2092	24.3	24.3	24.2	24.8
2093	24.4	24.6	25.2	25.7
2094	24.2	24.0	24.3	24.7
2095	24.8	24.7	24.6	24.6
2096	24.8	24.6	24.4	24.5
2097	24.4	24.5	24.2	24.6
2098	24.4	24.2	24.7	24.8
2099	24.3	24.4	25.7	25.1
2100	24.5	24.2	24.0	24.8

2. Appendix 4B: Global Climate Models RCP 4.5

Zambia analysis RCP4.5				
Year	ES-CLMcom	ES-RCA4	EL-CLMcom	LR-RCA4
1951.0	22.3	22.2	21.7	21.7
1952.0	22.2	22.6	22.1	21.7
1953.0	22.7	22.5	22.4	22.4
1954.0	22.5	22.3	21.9	21.8
1955.0	22.2	21.8	22.2	22.1
1956.0	22.4	22.0	22.3	22.0
1957.0	22.2	22.1	22.3	22.0
1958.0	22.4	21.9	22.1	21.7
1959.0	21.7	21.5	22.0	21.7
1960.0	22.5	22.5	21.7	21.5
1961.0	21.8	21.8	21.8	21.6
1962.0	22.2	22.2	22.1	22.0
1963.0	22.4	22.8	22.4	22.3

Zambia analysis RCP4.5				
Year	ES-CLMcom	ES-RCA4	EL-CLMcom	LR-RCA4
1964.0	22.1	22.1	21.8	22.0
1965.0	22.6	22.1	21.7	21.7
1966.0	22.1	22.2	21.5	21.4
1967.0	22.2	22.2	22.0	21.7
1968.0	22.4	22.3	22.5	22.4
1969.0	22.8	22.4	22.5	21.6
1970.0	22.1	21.5	21.6	21.6
1971.0	22.1	22.1	22.4	22.3
1972.0	22.6	22.7	22.0	22.4
1973.0	22.7	22.7	22.2	22.4
1974.0	22.1	22.2	22.0	22.1
1975.0	22.8	22.4	21.8	21.9
1976.0	22.3	22.4	22.3	22.2
1977.0	22.5	22.5	22.8	22.5
1978.0	22.4	22.4	22.3	21.9
1979.0	22.8	22.4	22.2	22.1
1980.0	22.5	22.2	22.6	22.9
1981.0	21.8	22.1	22.7	22.7
1982.0	21.8	21.5	22.1	22.3
1983.0	22.8	22.7	22.0	22.0
1984.0	22.0	22.5	22.1	22.1
1985.0	22.2	22.6	22.2	22.3
1986.0	22.6	22.6	22.2	22.5
1987.0	22.4	22.8	23.1	22.9
1988.0	22.4	22.5	22.4	22.5
1989.0	22.9	22.4	22.7	22.9
1990.0	22.1	21.9	23.3	23.4
1991.0	22.3	21.8	22.9	22.8

Zambia analysis RCP4.5				
Year	ES-CLMcom	ES-RCA4	EL-CLMcom	LR-RCA4
1992.0	22.6	22.2	21.8	22.1
1993.0	22.7	22.3	21.7	21.8
1994.0	22.7	22.7	22.0	22.0
1995.0	22.8	22.4	22.3	22.3
1996.0	22.3	22.2	22.4	22.4
1997.0	22.4	22.5	22.3	22.4
1998.0	22.7	22.4	22.9	22.8
1999.0	22.7	22.7	23.0	22.7
2000.0	22.5	22.5	22.7	22.4
2001.0	22.4	22.9	22.8	22.2
2002.0	23.1	23.1	22.9	22.9
2003.0	22.9	22.8	23.4	23.3
2004.0	22.5	22.6	23.0	22.7
2005.0	23.0	22.8	22.8	22.6
2006.0	23.5	23.6	23.0	22.6
2007.0	23.0	23.4	22.7	23.1
2008.0	23.2	23.0	23.1	23.2
2009.0	22.9	23.4	22.7	22.7
2010.0	23.1	22.8	22.9	23.1
2011.0	23.1	22.8	23.4	23.3
2012.0	22.7	22.7	23.2	23.5
2013.0	23.6	23.2	23.2	22.8
2014.0	23.3	23.5	23.2	23.1
2015.0	23.7	23.6	23.8	23.7
2016.0	23.4	23.7	24.0	23.9
2017.0	23.4	23.5	23.4	22.7
2018.0	23.5	23.8	22.9	22.4
2019.0	23.3	23.4	22.9	23.4

Zambia analysis RCP4.5				
Year	ES-CLMcom	ES-RCA4	EL-CLMcom	LR-RCA4
2020.0	23.5	23.7	23.4	23.5
2021.0	23.5	23.5	23.8	23.8
2022.0	23.9	23.9	22.9	22.8
2023.0	23.2	23.5	23.2	23.2
2024.0	23.7	23.3	23.1	23.2
2025.0	23.2	23.3	23.7	23.7
2026.0	23.9	23.4	23.8	23.3
2027.0	23.6	23.5	23.1	23.0
2028.0	23.6	23.7	23.4	23.1
2029.0	23.5	23.7	23.6	23.3
2030.0	23.3	23.6	23.3	23.2
2031.0	23.8	23.8	23.5	23.5
2032.0	24.0	24.2	23.9	24.5
2033.0	23.6	23.5	24.7	25.0
2034.0	23.3	23.4	23.9	24.2
2035.0	23.7	24.1	23.1	23.3
2036.0	24.4	24.1	23.7	24.0
2037.0	23.4	23.7	24.2	24.5
2038.0	23.2	23.4	23.8	23.3
2039.0	24.1	24.0	24.0	24.0
2040.0	23.7	24.0	23.7	24.0
2041.0	24.0	24.7	23.5	23.5
2042.0	23.9	24.3	23.3	23.5
2043.0	23.3	23.9	24.3	24.2
2044.0	23.6	24.1	24.4	24.4
2045.0	24.4	24.1	23.4	23.4
2046.0	24.0	24.3	23.4	23.6
2047.0	24.0	24.0	23.7	23.9

Zambia analysis RCP4.5				
Year	ES-CLMcom	ES-RCA4	EL-CLMcom	LR-RCA4
2048.0	24.4	24.3	24.0	24.0
2049.0	23.5	23.7	24.3	24.0
2050.0	23.4	24.1	24.3	23.9
2051.0	24.0	24.3	24.4	24.6
2052.0	23.8	24.2	24.6	24.7
2053.0	23.7	24.0	24.1	24.1
2054.0	24.3	24.7	24.0	24.1
2055.0	24.5	24.1	24.1	24.2
2056.0	24.5	24.3	23.7	23.7
2057.0	24.4	24.5	24.1	24.2
2058.0	23.9	24.2	24.5	24.6
2059.0	24.3	24.6	24.4	24.6
2060.0	24.5	24.7	23.7	24.0
2061.0	24.5	24.6	23.9	24.0
2062.0	24.6	24.3	24.6	25.3
2063.0	24.4	24.5	25.3	25.4
2064.0	24.7	24.7	24.6	24.5
2065.0	24.5	24.7	24.2	24.1
2066.0	23.8	24.0	24.4	24.2
2067.0	24.6	24.7	23.8	24.1
2068.0	24.6	24.9	24.1	24.1
2069.0	24.4	24.9	25.3	25.2
2070.0	24.8	25.0	25.1	24.7
2071.0	24.6	25.1	23.2	23.1
2072.0	25.0	24.9	23.6	23.7
2073.0	24.2	25.2	24.1	24.2
2074.0	25.2	25.2	24.9	25.0
2075.0	24.7	25.0	25.1	25.1

Zambia analysis RCP4.5				
Year	ES-CLMcom	ES-RCA4	EL-CLMcom	LR-RCA4
2076.0	25.1	25.2	24.2	24.4
2077.0	25.3	25.3	24.0	23.9
2078.0	25.2	25.6	24.0	24.3
2079.0	25.4	25.8	24.2	24.3
2080.0	25.1	25.6	25.3	25.3
2081.0	24.8	24.9	25.9	25.6
2082.0	24.6	24.6	24.9	24.3
2083.0	24.2	24.3	24.3	24.0
2084.0	24.4	25.0	24.1	24.2
2085.0	25.2	25.2	24.2	24.5
2086.0	25.3	25.5	24.9	24.7
2087.0	25.5	25.1	24.9	25.0
2088.0	25.0	25.3	24.6	24.5
2089.0	24.7	24.5	24.2	24.6
2090.0	24.9	25.3	24.8	24.8
2091.0	24.8	25.0	24.1	24.2
2092.0	24.8	24.9	23.7	24.2
2093.0	23.8	24.7	24.2	24.3
2094.0	24.4	24.5	25.0	24.5
2095.0	25.0	25.0	24.6	24.9
2096.0	24.9	25.2	24.7	25.0
2097.0	25.0	24.7	24.6	24.5
2098.0	25.3	24.9	24.0	24.1
2099.0	25.4	25.4	24.4	24.4
2100.0	24.5	25.3	24.4	25.1

Appendix 5: Global Climate Models, RCP 8.5, Source (SMHI, 2016)

1. Appendix 5A : Global Climate Models – Projected Temperature; RCP 8.5

Zambia Analysis RCP 8.5				
Year	CNRM-CLMcom	CNRM-RCA4	EC EARTH -CLMcom	EC EARTH RCA4
1951	22.3	22.5	22.2	22.4
1952	22.5	22.3	22.5	22.5
1953	22.2	22.0	21.9	21.7
1954	22.3	22.2	21.7	21.8
1955	22.4	22.4	21.9	22.2
1956	21.8	22.0	22.0	21.8
1957	22.3	22.4	21.9	22.3
1958	22.2	22.1	22.2	21.7
1959	22.3	22.1	22.0	22.3
1960	22.3	22.7	22.1	22.1
1961	22.0	22.2	22.4	22.5
1962	22.4	22.6	22.3	22.3
1963	22.3	22.0	21.6	21.6
1964	22.3	22.3	21.6	21.4
1965	22.7	22.5	21.7	21.9
1966	21.9	22.1	21.8	21.9
1967	22.1	22.4	22.1	21.8
1968	22.1	22.1	22.2	22.1
1969	22.0	21.9	21.8	22.1
1970	21.9	21.9	22.5	22.3
1971	22.3	22.8	22.0	22.0
1972	22.3	22.2	22.0	22.1
1973	22.5	22.3	21.7	22.0

Zambia Analysis RCP 8.5				
Year	CNRM-CLMcom	CNRM-RCA4	EC EARTH - CLMcom	EC EARTH RCA4
1974	22.6	22.3	22.5	22.1
1975	22.2	22.3	22.1	22.0
1976	22.1	22.7	22.1	22.2
1977	22.0	22.6	22.6	22.2
1978	22.4	22.8	22.5	21.9
1979	21.8	22.3	22.3	22.2
1980	22.4	22.4	22.8	22.6
1981	23.2	22.7	22.6	22.0
1982	22.2	21.9	22.2	22.1
1983	22.1	22.0	22.2	22.1
1984	22.2	22.6	22.2	22.5
1985	22.2	22.3	22.4	22.3
1986	22.3	22.6	22.7	22.5
1987	22.7	22.6	22.4	22.0
1988	22.7	22.7	22.6	22.8
1989	22.5	22.5	22.5	22.5
1990	22.7	22.5	22.6	22.7
1991	22.2	21.8	22.8	22.6
1992	22.2	22.0	22.0	22.5
1993	22.1	22.2	22.6	22.2
1994	22.7	22.5	22.0	22.4
1995	22.7	22.8	22.9	22.4
1996	22.4	22.5	22.6	22.8
1997	22.6	22.5	22.6	22.9
1998	22.7	22.7	22.3	22.7
1999	22.6	22.2	22.7	22.6
2000	22.4	22.9	23.2	23.2

Zambia Analysis RCP 8.5				
Year	CNRM-CLMcom	CNRM-RCA4	EC EARTH - CLMcom	EC EARTH RCA4
2001	23.0	23.2	22.3	22.6
2002	22.6	23.1	22.9	22.7
2003	22.8	22.8	22.7	22.7
2004	22.6	23.0	22.8	22.9
2005	23.0	22.7	22.5	22.7
2006	23.2	22.7	22.4	22.6
2007	22.9	22.9	23.0	22.7
2008	22.9	22.8	22.8	22.6
2009	22.9	22.8	23.4	23.1
2010	22.6	22.8	23.1	23.5
2011	23.0	23.2	23.3	23.1
2012	22.9	22.7	23.3	23.0
2013	22.8	23.1	23.5	23.2
2014	23.0	22.9	23.1	22.6
2015	22.8	23.1	23.1	23.1
2016	22.8	23.3	23.3	23.1
2017	24.0	23.6	22.8	23.2
2018	22.9	23.2	22.9	23.3
2019	23.3	23.2	23.3	23.5
2020	23.2	22.8	23.5	23.5
2021	23.1	23.4	23.1	23.2
2022	23.3	23.3	23.4	23.7
2023	22.7	22.8	23.9	23.8
2024	22.9	23.4	23.8	23.4
2025	23.0	22.9	23.5	23.6
2026	23.6	23.6	23.5	23.8
2027	23.4	23.4	23.7	23.8

Zambia Analysis RCP 8.5				
Year	CNRM-CLMcom	CNRM-RCA4	EC EARTH -CLMcom	EC EARTH RCA4
2028	23.2	23.1	23.9	23.4
2029	23.2	23.6	23.3	23.6
2030	23.8	23.6	24.3	24.2
2031	23.4	23.5	23.6	23.3
2032	23.4	23.8	23.7	23.7
2033	23.6	23.9	24.2	23.8
2034	23.2	23.0	24.0	23.9
2035	22.7	23.5	23.8	23.8
2036	24.0	24.2	23.4	24.2
2037	23.0	23.4	23.7	23.9
2038	23.3	23.5	23.7	24.1
2039	23.9	24.2	23.9	24.0
2040	23.5	23.5	24.2	24.0
2041	23.6	23.8	24.1	23.9
2042	24.1	23.7	23.9	24.1
2043	24.0	23.7	24.0	24.4
2044	24.0	23.6	24.8	24.9
2045	24.0	24.3	24.6	24.3
2046	23.9	24.1	24.1	24.1
2047	24.0	23.9	24.2	24.5
2048	23.6	24.0	24.7	24.5
2049	23.6	24.0	23.7	24.0
2050	24.0	24.1	24.1	24.4
2051	23.9	23.8	24.9	25.2
2052	24.1	24.0	25.0	25.2
2053	24.7	24.5	24.1	24.2
2054	24.4	24.5	24.5	24.7

Zambia Analysis RCP 8.5				
Year	CNRM-CLMcom	CNRM-RCA4	EC EARTH - CLMcom	EC EARTH RCA4
2055	24.0	24.5	24.1	24.9
2056	24.2	24.3	24.7	24.8
2057	24.6	24.6	24.9	25.0
2058	24.5	24.7	24.2	24.8
2059	24.7	24.7	24.9	24.9
2060	25.0	24.5	25.2	25.4
2061	24.3	24.5	24.7	25.1
2062	24.2	24.5	24.4	24.6
2063	24.4	24.5	25.1	25.1
2064	24.7	25.0	25.6	25.6
2065	24.4	24.4	25.9	25.3
2066	24.5	25.0	25.0	24.9
2067	25.4	25.5	25.6	25.7
2068	25.1	25.2	25.0	25.5
2069	24.9	25.0	25.5	25.8
2070	24.6	24.8	25.5	25.6
2071	24.9	25.2	25.3	25.6
2072	25.5	25.6	25.5	25.5
2073	24.7	25.0	26.0	26.0
2074	25.4	25.3	25.5	25.6
2075	25.8	25.6	25.9	25.9
2076	24.8	25.1	25.9	26.2
2077	25.7	25.6	25.5	26.0
2078	25.5	25.8	25.5	26.0
2079	25.5	25.7	26.0	25.9
2080	25.7	26.0	26.2	26.6
2081	25.3	25.7	25.8	26.2

Zambia Analysis RCP 8.5				
Year	CNRM-CLMcom	CNRM-RCA4	EC EARTH - CLMcom	EC EARTH RCA4
2082	26.0	25.9	25.7	26.0
2083	25.4	25.5	27.0	26.5
2084	26.4	26.0	26.3	26.2
2085	25.5	25.7	25.6	26.4
2086	25.2	26.3	26.1	26.6
2087	26.1	25.9	26.3	26.4
2088	25.7	26.1	26.9	27.2
2089	26.2	26.1	27.1	27.2
2090	25.9	26.1	26.2	25.9
2091	27.0	26.2	26.1	27.1
2092	26.1	26.6	27.0	27.1
2093	26.7	26.7	27.3	27.9
2094	26.5	26.5	26.9	27.3
2095	26.5	26.5	27.2	27.3
2096	26.1	26.1	26.7	27.1
2097	26.8	26.7	26.9	27.1
2098	26.4	26.6	26.9	27.1
2099	26.5	26.8	27.4	28.2
2100	26.3	26.3	27.3	27.6

2. Appendix 5_B : Global Climate Models – Projected Temperature; RCP 8.5

Zambia Analysis RCP 8.5				
Year	ES-CLMcom	ES-RCA4	LR-CLMcom	LR-RCA4
1951.0	22.4	22.2	21.7	21.7
1952.0	22.3	22.6	22.1	21.7
1953.0	22.7	22.5	22.5	22.4
1954.0	22.5	22.3	21.9	21.8
1955.0	22.2	21.8	22.2	22.1
1956.0	22.4	22.0	22.3	22.1
1957.0	22.2	22.0	22.3	22.0
1958.0	22.4	21.9	22.1	21.8
1959.0	21.7	21.5	22.0	21.7
1960.0	22.5	22.5	21.7	21.6
1961.0	21.8	21.8	21.8	21.7
1962.0	22.2	22.2	22.2	22.1
1963.0	22.4	22.8	22.4	22.3
1964.0	22.1	22.0	21.8	22.0
1965.0	22.6	22.1	21.7	21.7
1966.0	22.1	22.1	21.5	21.4
1967.0	22.2	22.2	22.0	21.8
1968.0	22.4	22.3	22.5	22.5
1969.0	22.9	22.4	22.5	21.7
1970.0	22.2	21.5	21.6	21.6
1971.0	22.2	22.1	22.4	22.3
1972.0	22.7	22.7	22.0	22.4
1973.0	22.7	22.7	22.2	22.5
1974.0	22.1	22.2	22.0	22.1
1975.0	22.8	22.4	21.8	21.9
1976.0	22.3	22.4	22.3	22.3
1977.0	22.5	22.5	22.8	22.5

Zambia Analysis RCP 8.5				
Year	ES-CLMcom	ES-RCA4	LR-CLMcom	LR-RCA4
1978.0	22.4	22.4	22.4	21.9
1979.0	22.8	22.4	22.2	22.2
1980.0	22.6	22.2	22.6	23.0
1981.0	21.8	22.0	22.7	22.7
1982.0	21.8	21.5	22.1	22.4
1983.0	22.8	22.7	22.0	22.0
1984.0	22.0	22.5	22.1	22.2
1985.0	22.2	22.6	22.2	22.4
1986.0	22.7	22.6	22.2	22.5
1987.0	22.5	22.8	23.1	22.9
1988.0	22.4	22.5	22.4	22.6
1989.0	22.9	22.4	22.7	22.9
1990.0	22.1	21.9	23.3	23.5
1991.0	22.3	21.8	22.9	22.9
1992.0	22.6	22.2	21.8	22.1
1993.0	22.7	22.3	21.7	21.8
1994.0	22.7	22.7	22.0	22.0
1995.0	22.9	22.4	22.3	22.3
1996.0	22.3	22.2	22.4	22.4
1997.0	22.5	22.5	22.3	22.5
1998.0	22.7	22.3	23.0	22.9
1999.0	22.7	22.7	23.1	22.7
2000.0	22.5	22.5	22.7	22.5
2001.0	22.5	22.9	22.8	22.3
2002.0	23.1	23.2	22.9	22.9
2003.0	22.9	22.8	23.5	23.3
2004.0	22.5	22.6	23.0	22.8
2005.0	22.5	22.9	22.8	22.6

Zambia Analysis RCP 8.5				
Year	ES-CLMcom	ES-RCA4	LR-CLMcom	LR-RCA4
2006.0	23.1	23.1	22.5	22.6
2007.0	23.1	23.3	22.9	22.7
2008.0	23.1	23.4	22.5	22.8
2009.0	23.1	23.6	23.0	22.7
2010.0	23.3	23.7	23.1	22.8
2011.0	23.4	23.3	23.5	23.2
2012.0	23.2	22.5	23.1	23.2
2013.0	23.2	23.0	24.4	24.0
2014.0	23.2	23.5	23.6	23.7
2015.0	23.3	23.7	24.2	24.4
2016.0	23.5	23.7	23.7	23.7
2017.0	23.8	23.4	23.6	23.5
2018.0	23.6	23.4	23.1	23.2
2019.0	24.0	24.0	23.1	22.7
2020.0	23.6	23.4	23.7	23.6
2021.0	23.6	23.8	24.5	24.0
2022.0	23.8	23.8	23.9	23.5
2023.0	23.9	23.6	23.3	23.0
2024.0	23.8	23.6	23.4	23.1
2025.0	23.9	23.7	23.6	23.8
2026.0	24.1	23.9	23.7	24.5
2027.0	23.8	23.5	24.2	23.8
2028.0	23.3	23.5	23.2	23.3
2029.0	23.8	23.8	23.5	23.5
2030.0	23.5	23.8	23.3	23.4
2031.0	24.0	24.1	23.1	23.1
2032.0	24.1	24.3	23.4	23.4
2033.0	23.8	23.6	24.6	24.7

Zambia Analysis RCP 8.5				
Year	ES-CLMcom	ES-RCA4	LR-CLMcom	LR-RCA4
2034.0	24.4	24.7	24.3	24.9
2035.0	24.4	24.6	23.5	23.9
2036.0	24.2	24.3	23.2	23.2
2037.0	24.1	24.3	23.5	24.1
2038.0	24.1	24.4	23.8	23.8
2039.0	23.8	24.2	24.5	24.4
2040.0	24.2	24.5	24.2	24.2
2041.0	24.2	24.4	23.5	23.9
2042.0	24.1	24.2	24.3	24.4
2043.0	24.4	24.2	25.1	25.4
2044.0	24.3	24.2	24.5	24.3
2045.0	24.4	24.5	23.8	23.8
2046.0	24.7	24.9	23.6	23.7
2047.0	24.7	24.7	24.4	24.2
2048.0	24.5	24.9	24.4	24.4
2049.0	25.0	25.1	23.8	23.8
2050.0	24.1	24.4	24.2	24.5
2051.0	24.3	24.5	24.1	24.6
2052.0	24.6	24.8	24.0	24.2
2053.0	24.3	25.0	25.0	25.3
2054.0	24.7	25.2	25.5	26.1
2055.0	24.4	25.2	25.0	25.0
2056.0	25.1	25.4	24.9	24.8
2057.0	25.6	25.9	24.2	24.5
2058.0	25.7	25.8	24.6	24.7
2059.0	25.3	25.4	25.0	25.5
2060.0	25.6	26.2	25.2	25.2
2061.0	25.0	25.7	24.8	25.2

Zambia Analysis RCP 8.5				
Year	ES-CLMcom	ES-RCA4	LR-CLMcom	LR-RCA4
2062.0	25.0	25.2	25.0	25.2
2063.0	25.7	25.9	25.2	25.6
2064.0	25.2	25.5	25.2	25.2
2065.0	25.1	25.6	25.0	24.9
2066.0	25.8	26.0	25.4	25.4
2067.0	25.9	26.0	25.4	25.5
2068.0	25.6	25.9	25.1	25.5
2069.0	25.6	25.8	26.2	26.8
2070.0	26.4	26.2	25.2	25.4
2071.0	26.0	26.3	25.3	25.6
2072.0	25.6	25.7	26.0	26.2
2073.0	25.6	26.0	27.0	27.0
2074.0	25.9	26.5	25.6	26.0
2075.0	26.5	26.6	25.5	25.8
2076.0	26.0	26.5	25.9	26.3
2077.0	26.1	26.8	26.8	26.9
2078.0	26.4	27.1	26.8	27.4
2079.0	26.3	26.5	25.9	26.3
2080.0	26.6	26.7	25.3	25.6
2081.0	26.3	26.7	26.3	26.3
2082.0	26.2	26.8	26.3	26.7
2083.0	27.1	27.4	26.5	26.6
2084.0	27.1	27.2	27.2	27.4
2085.0	26.7	27.2	26.4	26.6
2086.0	26.8	26.8	25.8	26.5
2087.0	27.1	27.0	26.6	26.7
2088.0	26.8	27.3	27.9	27.8
2089.0	26.8	27.4	26.9	26.8

Zambia Analysis RCP 8.5				
Year	ES-CLMcom	ES-RCA4	LR-CLMcom	LR-RCA4
2090.0	26.9	27.4	26.5	26.9
2091.0	27.0	27.5	26.8	26.8
2092.0	26.4	26.8	26.5	26.9
2093.0	27.0	27.3	27.4	27.9
2094.0	26.7	27.8	26.8	27.9
2095.0	27.1	27.4	26.4	26.5
2096.0	27.3	27.2	27.0	27.1
2097.0	27.2	27.6	27.6	28.0
2098.0	27.5	27.5	27.8	27.8
2099.0	27.3	27.0	27.3	28.1
2100.0	28.9	27.2	27.1	27.2

Appendix 6: Ethical clearance