DEMOCRATIC AND POPULAR REPUBLIC OF ALGERIA

Ministry of Higher Education and Scientific Research

University of Tlemcen

PAN AFRICAN UNIVERSITY

Institute for Water and Energy Sciences (Incl. Climate Change)

WATER DEMAND SIMULATION USING WEAP 21:

A CASE STUDY OF THE MARA BASIN, KENYA

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Academic Year: 2015-2016

WATER DEMAND SIMULATION USING WEAP 21: A CASE STUDY OF THE MARA RIVER BASIN, KENYA

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE DEGREE OF MASTER IN WATER (ENGINEERING TRACK) AT THE PAN AFRICAN UNIVERSITY, INSTITUTE OF WATER AND ENERGY SCIENCES (INCLUDING CLIMATE CHANGE), TLEMCEN, ALGERIA

DECLARATION

This is my original work and has not been submitted to any university for the award of a degree. Works obtained from earlier publications and studies have been well referenced and cited appropriately in this work.

Signature:  Date ……26/08/2016……

OSORO METOBWA MARCELLUS GEORGE.

DEDICATION

TO THE PURE OF HEART, MAY THE GLOW SHINE FOR ETERNITY.

ACKNOWLEDGEMENT

I give thanks to the Lord Almighty for the opportunity he granted me to pursue this Degree until completion.

My gratitude to the African Union and the African Union Commission (AUC), the German Ministry of Foreign Affairs, for awarding me the scholarship that enabled my postgraduate studies. the Algerian Government for facilitating my stay in Algeria.

My parents Mr Boniface Osoro and Mrs Stella Gesare, the support you gave me is priceless. May the Lord hold you close for ever. I am grateful. Tom, Clinton, Alice you are appreciated.

My gratitude to my supervisor Prof Lars Ribbe, for the support criticism and help given during the process, and to Professor Chabane Sari for the encouragement and desire to see me through. To the Director PAUWES, Dr. Zerga for the constant zeal and zest to ensure all the academic and non-academic components of my stay in the Institute were sorted. To the PAUWES and GIZ/DAAD staff and my fellow colleagues in PAUWES, for the encouragement, criticism and hunt for enlightenment during these two years. May the path stay true.

My sincere appreciation to the staff at ITT, TH Koln, especially Mr. Sven, Tatiana, Mario, Juan and Khallifa for their support. Mr Johnson Maina (Dir. Hydro Climatology) of the Kenya Meteorological Department, Professor James Kungu of Kenyatta University, Mrs Eunice Ochieng of WRMA, Mr Michael Mulongo of NWPC Kenya and Professor Mohammed Hassan of the IGAD climate forecast office for their valuable assistance during the study.

Lastly, to my Family and friends, my heartfelt gratitude for standing by me during this period. May your sacrifice be blessed.

ABSTRACT

The competing water uses within the Mara Basin has resulted into increased water demand on the mara river. The water evaluation and planning system (WEAP) was utilized to assess various ways to alleviate the river stress. In a bid to assess the impact of possible alleviation measures, diverse demand management strategies such as water reuse, use of more efficient equipments and policies were analysed. Water uses in the basin were quantified, mapped in regards to their current uses and demands. This established the baseline for future forecasts. The Parameter Estimation Tool (PEST) was used in model calibration. The year 2010 was used as a base year for scenario simulations up to the year 2045 due to few data gaps in the data available. From the results, the water demand within the basin under the reference scenario is 49.1 BCM, the demand drops to 4.1 BCM under the DMS scenario and to 3.5 BCM under the enhanced policy implementation and DMS scenario. The unmet demand under the reference scenario is 13.0 BCM mostly at the irrigation nodes at Nyangores and the downstream large scale farms. By embracing the proposed demand management strategies explored, the sector specific total water demand is projected to decline by 92.87% by the year 2045.

Keywords: Mara Basin, WEAP, water demand management, water demand, Kenya

Résumé

Les divers usages de l'eau dans le bassin de Mara ont entraîné une demande accrue en eau sur la rivière Mara. Le Système d'Evaluation et de Planification des Eaux (WEAP) a été utilisé pour évaluer les divers moyens en vue d'atténuer le stress que subit la rivière. Dans le but d'évaluer l'impact des possibles mesures d'atténuation, diverses stratégies de gestion de la demande telle à diverses telle que : la réutilisation de l'eau, l'utilisation des équipements et des politiques plus efficaces ont été analysées. Les usages de l'eau dans le bassin ont été quantifiés, cartographiés en ce qui concerne leurs utilisations et demandes actuelles. Ceci établissant la référence pour les futures prévisions. L'Outil d'Estimation des Paramètres (PEST) a été utilisé dans l'étalonnage du modèle. L'année 2010 a été utilisée comme année de base pour la simulation des scénarii jusqu'en 2045 en raison de quelques lacunes dans les données disponibles. En guise de résultats, la demande en eau dans le bassin dans le scénario de Référence est de 49,1 milliards de mètres cubes. Cette demande devient égale à 4.1 milliards de mètres cubes dans le scénario DMS et à 3,5 milliards de mètres cubes dans la mise en œuvre de la politique renforcée et scénario DMS. La demande non satisfaite dans le scénario de référence est de 13,0 milliards de mètres cubes principalement au niveau des nœuds d'irrigation à Nyangores et en aval des plantations à grande échelle. En adoptant les stratégies de gestion de la demande telles que proposées, la demande totale en eau spécifique du secteur devrait diminuer de 92,87% d'ici 2045.

Mots-clés : Mara Bassin, WEAP, la gestion de la demande en eau, la demande en eau, Kenya

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LIST OF ABBREVIATIONS AND ACRONYMS

BCM	Billion Cubic Metres
DMS	Demand Management Strategy/Strategies
EAC	East African Commission On the Lake Victoria Basin
GCM	Global Circulation Models
GoK	Government of Kenya
GWP	Global Water Partnership
IWRM	Integrated Water Resources Management
KES	Kenya Shillings
LVS-CMA	Lake Victoria South Catchment Area
MCM	Million Cubic Metres
MRB	Mara River Basin
MRBWAP	Mara River Basin Water Allocation Plan
NMM	North Mara Mines
NWPC	National Water and Pipeline Corporation
RVCA	Rift Valley Catchment Area
UN	United Nations
UNEP	United Nations Environmental Program
WEAP	Water Evaluation and Planning System
WRMA	Water Resources and Management Authority
WRUAS	Water Resource User Associations

Chapter One: INTRODUCTION

1.1 Research Background

Water is fundamental for the sustenance of human life and the diverse aquatic settings. Water has a critical role in the irrigation, industry, businesses and power generation. Dublin principle recognizes fresh water as a finite and vulnerable resource requisite for many different purposes, functions and services (Xie, 2006). Global Water Partnership (GWP) has demonstrated that actions by human beings reduce the quality and availability and of water by actions, which result in the alterations of flow regimes within surface water systems (GWP, 2000).

Both surface water resource and groundwater resources act the earth's fresh water reservoirs. A country's freshwater availability is determined by the rate by which this water is renewed yearly. A nation is "water stressed" when its freshwater supplies in a year ranges from 1,000 to 1,7000 cubic meter per capita (World Bank, 2004). When a country has an annual renewable freshwater supplies of less than 1,000 cubic meter per capita, it is categorized as "water scarce."

World Bank (2000) has reported that Kenya's annual renewable freshwater is nearly 647 cubic meter per capita. Therefore, Kenya belongs to 8.3% of the nations in the world categorized as "water scarce," while a tenth of the world is believed to be "water stressed" (Mogaka, Gichere, Davis, & Hirji, 2006; UNEP, 2002).

In 2009, a study by Kronaveter and Shamir discerned that unsustainable water abstraction practices such as unsustainable ground water mining or water transfer facilities such as inter basin transfers result in more water withdrawals than the local available renewable resource.

In a study,(Schofield, Burt, & Connell, 2003) state that freshwater demand is continuously increasing and point out that such is due to the degradation of catchments, pollution of the resource, improper management and misuse of the available waters and also increased pressure due to an increasing population. This discernment is illustrated statistically in a study by Kucukmehmetoglu and Guldmann (2010) where they state that the ratio existing between consumption and renewable resources was at 7% in 1990 but is projected to reach 9% in 2025 and 11% in 2050.

Global Water Partnership (2000) believes that the water abstraction rose by a factor of seven while population increased by a factor of three, a third of these people reside in waters that experience medium to high water stress in the last hundred years. Kenya's freshwater supply reduced from 1,853 cubic metres per capita in 1969 to 647 cubic metres per capita in 1992 (Mogaka, Gichere, Davis, & Hirji, 2006) and to the current 650 cubic metres in 2010 (GoK,2012).

Particularly, this is lower than the suggested world's annual ranking of 1,000 cubic metres per person. This scenario is a recipe for conflict between communities over the dwindling resources. (Whisnant,2010).

Kenya has adopted the integrated water resources management strategy (IWRM) at the catchment level in a bid to do rational planning and management. Since water is moving from one region to another, the approach by Kenyan government will assist in the management of the water resources.

The envisioned goal is synchronized expansion and administration of the water without sacrificing the vitality and sustainability of vital ecosystems (GWP, 2001). The recent legislative instruments such as the Water Act 2002 and Water Act 2014 are keen on institutional development with particular emphasis on catchment management strategies and mechanisms hence the **consolidation of water uses** and the integration of water users in the planning, allocation and management frameworks. These sectoral reforms are poised in a progressive manner with an end goal to bring about basic and critical changes in the manner that water is shared amongst the various uses and users. The aim is to ensure the balance between sustainability, equity and efficiency is achieved in all water allocations (GoK, 2002).

Kenya has six major catchment areas (*Figure* 1.1). These areas are spatially distributed and are greatly influenced by the surrounding geology and morphological features. These catchments include; the rift valley catchment, Tana catchment, the Lake Victoria (North and South) basin, Athi catchment, and the Ewaso Ng'iro catchment. The catchments lie in different climatic conditions, the Ewaso Ng'iro and Athi basins lie in semi-arid environments while the Lake Victoria and the Tana basins lie in humid environments.

Water resources availability varies spatially and temporary in Kenya (GoK,2006). Given this trend, the water availability in the Lake Victoria South catchment area and the Mara river basin in particular has been experiencing a decline in recent times occasioned by factors such as population growth, increase in socio-economic activities (WRMA,2008).

The anthropocentric nature of water management surmises that water demand is not a projection of sectorial water needs but also a resultant event due to consumption behavioural change bearing in mind the adaptation to water scarcity (Griffen 2006).

Prevailing factors such as the political, legal, moral backings, soft decision inputs and competing economic water uses render water allocation into a complex socio-economic and ecological balance. In line with the Dublin principles, especially the ones of equity and equality, an efficient mechanism that estimates the water availability, supply and demand needs, evaluation criteria and response mechanism is needed.

In a 2006 study, Mogaka *et al* state that currently Kenya has developed about 15% of its waters making available 4.3 cubic metres of water per person storage. According to previous studies (Saifuka & Ongsomwang, (2003), there is need to develop high productivity and catchment carrying capacity sustaining the quality of the environment, land and aquatic resources.

This is in cognizance of the fact that increased land and water catchment zone pressures have a direct impact on renewable water resources. (Akivanga, Otieno, Kipkorir, Kibiiy, & S, 2010).

Figure 1:1: Map showing the catchment areas in Kenya.

Human beings reduce the availability and quality of water through various actions, which alter flow regimes within surface water systems (GWP, 2000). This statement is evident within the Mara basin given the various anthropogenic activities that occur within it such as large scale farming, Ranches, Urban and rural settlements and tourism activities.

The Mara river thus forms the life line to all these socio economic ventures. Given the huge per capita demand on the resource and the reduction of its headwater capture basin covers that is occasioned by the destruction of the Mau forest that generates the distributary of Mara river. Water challenges in the Mara basin are due to unmet demand needs in the basin and in the surrounding watershed areas (Gereta, Wolanski, Borner, & Serneels, 2002).

Recent quantitative studies (Dessu, Melesse, & Bhat, 2013) (Hoffman, 2007) show that the available water cannot meet the competing sectoral demands due to increasing population and environmental degradation. Such a situation necessitates the development of mechanisms to ensure equitable distribution between man and nature.

This is only possible if the people attach value to the resource and identify possible trade- offs between the diverse users. Such initiatives will ensure equitable management given that priority was based on sustainable ecological - social benefits grounded on increasing water use efficiency, improved economic gains, mitigated hydrological variations and accommodated socio-political gains/water rights.

This study sets forth to evaluate the potential effects that water resources planning and water rights have by comparing demand to water availability at ecologically relevant time scales.

A study conducted in Syria utilising WEAP (Khalood, 2012) with regards to ways of combating water shortages in arid and semi-arid areas, give positive results on the use of grey water recycling as one of the methods that can be employed. Closer home, the WEAP model has been employed in Somalia to assess irrigation and competing water demands on the Juba and Shebelle river basin by Sebat (Sebhat, 2015).Several studies (Akivanga, Otieno, Kipkorir, Kibiiy, & S, 2010) Jenkins et al., 2005, Mutiga et al., 2010) have been done using weap on water allocation for various uses in different catchments in Kenya.

1.2 PROBLEM STATEMENT

The high water use for the relevance of industrial, domestic use and agricultural development in Mara region has led to decrease of the quantity of renewable water available. The high abstraction rate is due to lack of hydrological knowledge, unimplemented water rights and ignorance to environmental water demands.

Besides, the need to satisfy water demands for both economic and social development in the Mara basin have led to conflicts due to lack of equity in the allocation method and permit system. The existing water allocation strategies and permit system have optimized the rate of water abstraction because they have largely relied on a “first come, first serve” approach, instead of determining maximum water use for ecological benefits.

The rising demand for water resource with lack of demand management measures, projects that demand will outweigh the existing supply. Use of modelling tools to assess the basin’s ability to sustain its water demand in future coupled with scenario analysis will afford water resource management in Mara River Basin an opportunity to forecast and evaluate the impacts of different possible future trends and management strategies before implementation.

1.3 Objectives of The Study

Main Objective

The main focus of this study is the water demand simulation using Water Evaluation and Planning (WEAP) in the Mara River Basin.

Specific Objectives

i. Simulate water demand scenarios for effective water management using WEAP.

Research questions

The study was guided by the following set of questions;

i. What is the current water demand scenario?
ii. Which demand management strategies can be used?
iii. Which strategies could be implemented?

1.4 Justification of the study

The study will provide an in-depth knowledge on water demand (spatial- temporal) within the MRB, which is key to implementation of water allocation by WRMA among implementation of other key government policies. By taking into account the amount of water already licensed for abstraction and how much water is needed, it is possible to determine where abstraction for consumptive purposes is allowed and sections of the river with deficits are identified in advance. The scenarios will provide a starting point for dialogue among interested parties about various options for allocation of water resources and the possible trade-offs therein.

The use of WEAP modelling tool in the study with emphasis on scenario analysis approach will enhance development of sound water governance mechanisms and realization of integrated management of the basin since it provides an opportunity to water resource managers and users to forecast and evaluate the impacts of different possible future trends and management strategies before implementing them.

Determination of water demand within the basin will provide a basis for allocation and permitting of water resources in the basin. Mara River basin modelling using WEAP tool will assist in evaluating watershed health, quantify anthropogenic influences in the watershed and developing a program to ensure a sustainable water resource.

Water abstraction within the Mara basin has increased in recent times due to an influx of socio-economic activities. Currently the Mara river is classified as being in an ALERT state by the National Water Resources Management Authority (WRMA), based on the declining water levels and deteriorating water quality hence the need for intervention that this study will make a contribution to.

1.5 Reforms within the Water Sector in Kenya

The time period between the late 1980s to the 1990s formed a critical transition period for the water sector in Kenya. Reports occasioned by the water resources assessment programme (WRAP) and the 1992 National Water Master Plan highlighted the challenges of the Water Act of 1972. These were addressed in the water policy of 1999 that eventually morphed into the Water Act of 2002. The Water Act of 2002 lead to the separation of functions within the water sector. The management of natural resources, the provision of services and the formulation of policies and oversight was separated. The management was bestowed on the Water Resources Management Authority (WRMA). The national WRMA office located in Nairobi regulates the activities of the regional offices, while the service provision function was given to the Water Services Regulatory Board (WSRB). The national government retained the role of policy formulation. Subsequent review and fine tuning of this act resulted in the Water Act of 2014. The institutional framework is illustrated *Fig*ure 1.2;

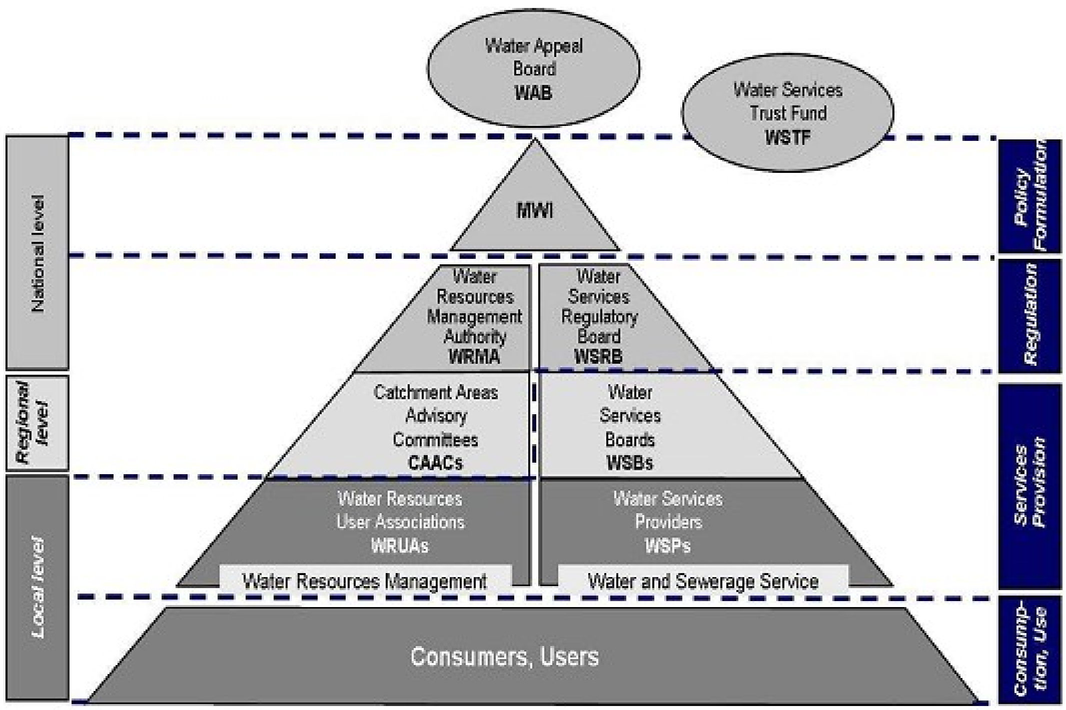

Figure 1:2 institutional framework of the Kenyan water sector.

Changes that came about by the Water Act of 2002 touched on various aspects. One such shift was on management of the resources whereby a new system was embraced. The new Water Act brought about the concept of catchment based management approach. Based on this strategy a drainage network was established and the contributing areas delineated. As a result, six areas were identified namely; the Athi basin, Rift Valley, Tana, Ewaso Ng'iro north, Lake Victoria north and Lake Victoria south. They are shown in the *Fig*ure 1.3 below.

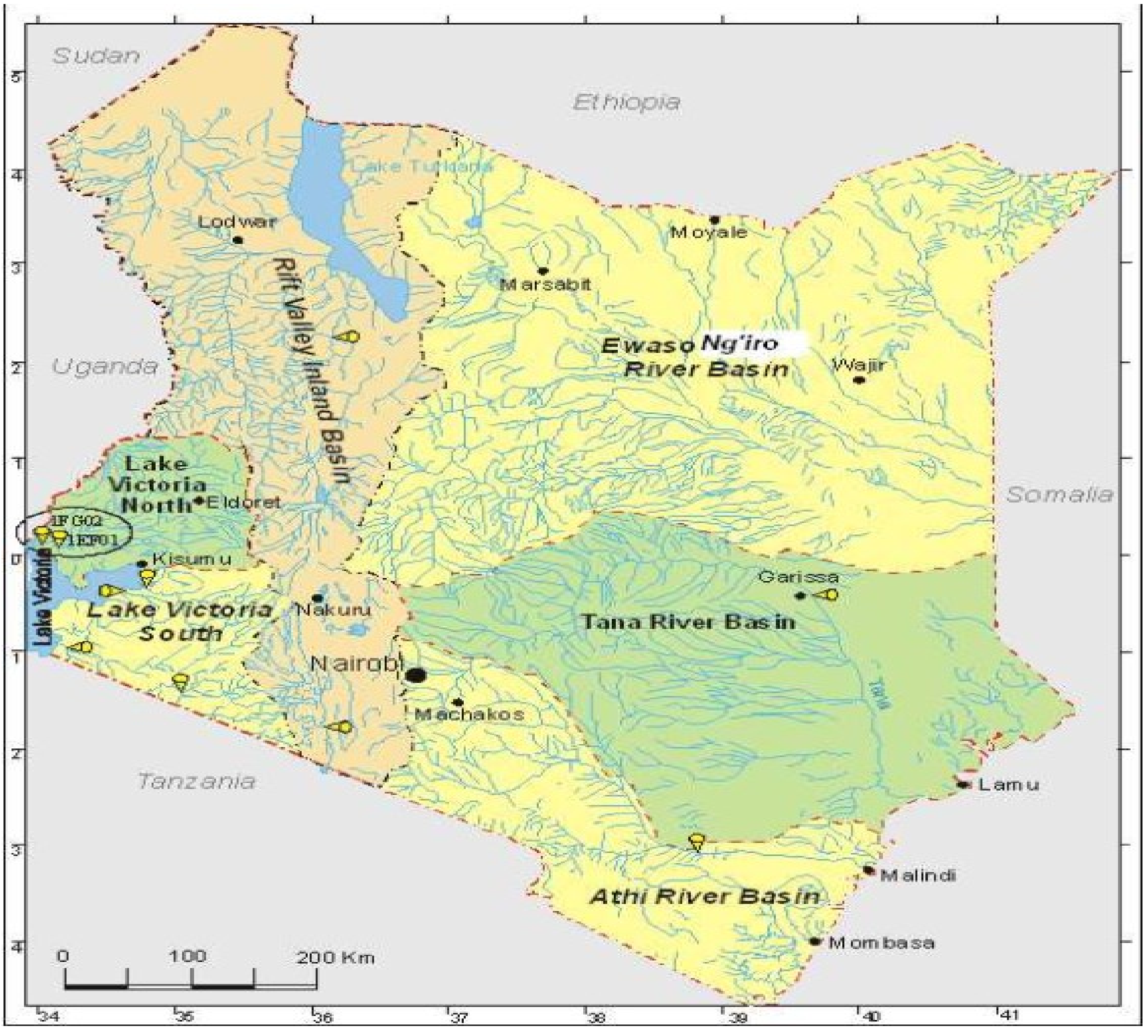

Figure 1:3 Catchment management areas in Kenya

The catchment demarcation also formed the basis of water board operational areas. The existing water boards called into effect by the Water Act 2002 are The Tana, Tana Athi, Rift Valley, Lake Victoria North, Lake Victoria South, Coastal, Northern Water Service Boards. The board grapple with diverse challenges in their bid to provide portable water and increase its accessibility that range from water quality and quantity to inter community conflicts.

The Water Act 2002 introduced the concept of water markets into the country whereby, water boards are authorized to license water providers and regulate them while the Water Resources Management Authority together with advisory boards at the catchment level evaluate and issue water use permits in a mechanism to regulate water use and improve on efficiency and economic value of water.

The Water Act 2002 also devolved management functions to the catchment stakeholders. This was achieved through the formation and recognition of catchment area advisory committees and of the water resource users' associations (WRUAS). The WRUAS are formed at sub-catchment level and are the critical link in the management chain at the grassroots level. This particular aspect buttresses the Dublin principles within the system and also promotes equity and equality within the community. The resultant effect is the profound sense of ownership of the resource by the residents hence improving the management infrastructure of the catchment and of a particular resource.

Currently a resource management strategy with a national outlook has been developed by WRMA and it outlines how the water resources are to be managed, protected, utilized and developed in a sustainable manner. Based on this framework the catchment areas have developed catchment strategies that are in line with this outlook and the national economic blue print vision 2030. The current policy shift is captured aptly in the water act 2002 as ensuring a balance between efficiency, sustainability and equity in all water allocations.

1.6 STUDY AREA

The Mara river is a transboundary resource shared between two countries; Kenya and Tanzania. It is located within the Mara river Basin(MRB) that stretches from the southern part of Kenya to the northern part of Tanzania. It is estimated that 65% of the MRB lies in Kenya while 35% is located in Tanzania. In Kenya it lies specifically within the districts of Bomet, Trans Mara, Nakuru and Narok. In Tanzania it lies in the following districts; Tarime, Musoma and Serengeti. Figure 1.4 below illustrates this visually.

The world renown tourist attraction game reserve the Maasai Mara is located entirely within this basin. Moreover, part of the Serengeti National park also lies within this basin.

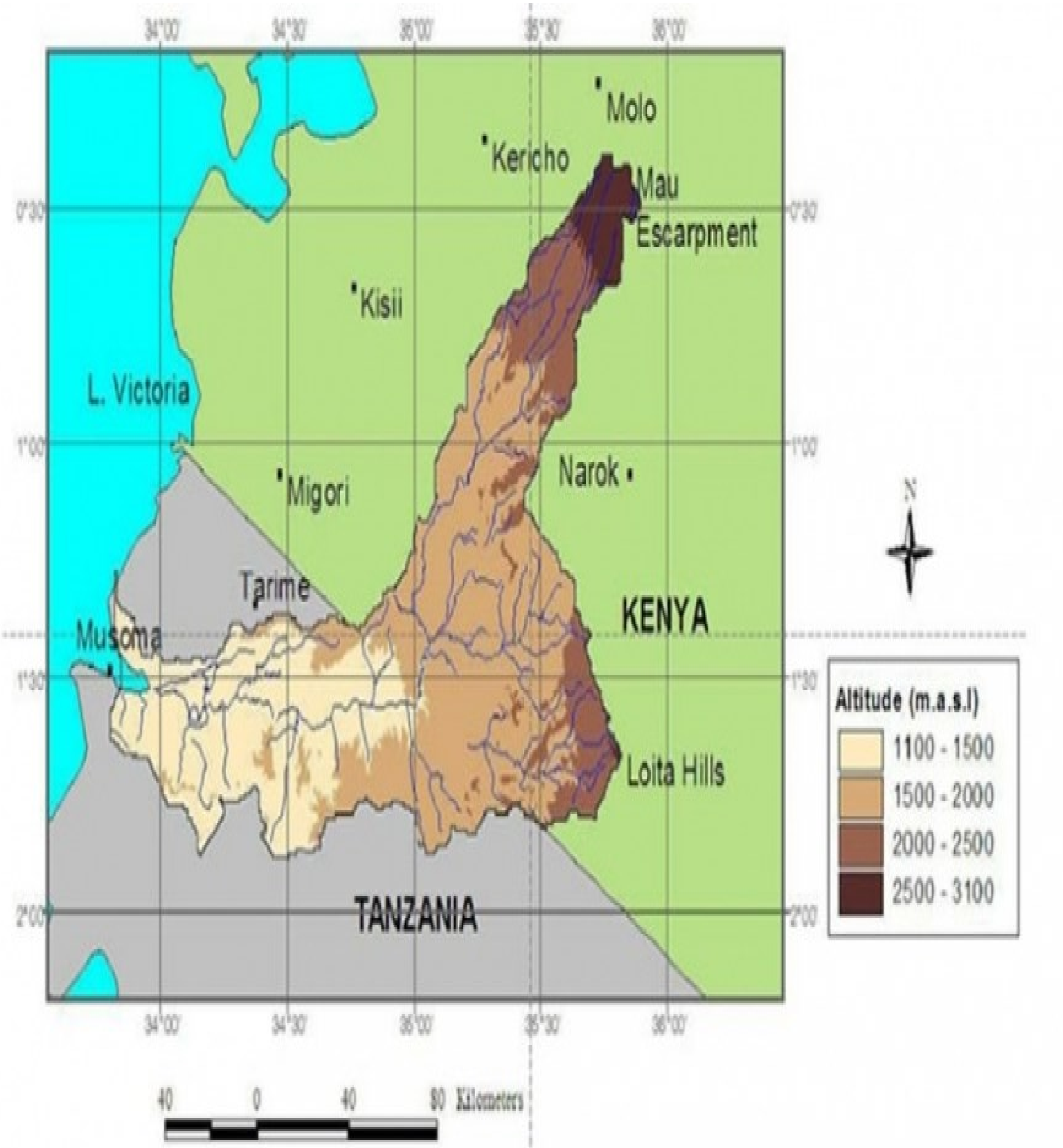

Figure 1:4 Map Mara basin boundaries

1.6.1 Hydrology of the Mara

The Mara River is one of the pristine rivers that pour their waters into Lake Victoria hence forming part of the Nile basin. It lies within two catchment/basin areas, the Lake Victoria South Catchment Management Area (LVS-CMA) and the Rift Valley Catchment Area (RVCA). It stretches for 395 kilometres and transcends two countries, (*figure 1.4*) Kenya and Tanzania, and provides a lifeline to one of the world's diverse eco-systems, the Mau Mara Serengeti ecosystem, that is home to two diverse flora and fauna that habit the Mau forest, Mara national park in Kenya and the Serengeti in Tanzania. The Mara River drains combined 13,750 km^2 area of South Western Kenya and North Western Tanzania before entering Lake Victoria at the Musoma bay.

The highest elevation of the basin is 3,062 meters above sea level at the upstream end and the lowest is 1138 meters above sea level at the downstream end of the river, this is illustrated in figure 1.5 below. The basin is inclined at an average slope of 6.9%. Mara River begins at the confluence of Amala River and Nyangores River as its main tributaries. These confluence distributaries run through sections of the Mau vegetation complex and through section of large and small scale farm land. At the Maasai Mara Game Reserve, Mara River is joined by Talek, Sand and Engare Ngobit rivers as its ephemeral tributaries. The Mara River then flows through the north of the Serengeti National Park then through the Mosirori flood plain before discharging into the Lake Victoria.

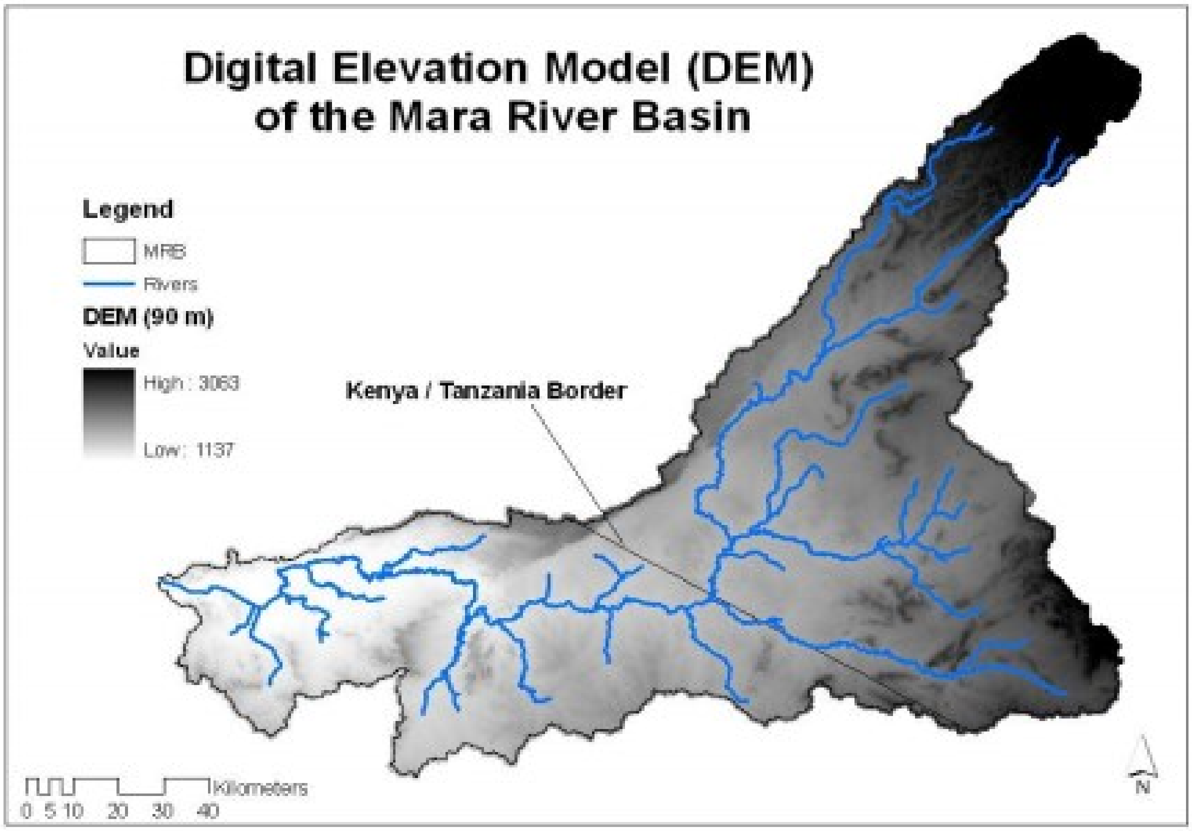

Figure 1:5 Digital Elevation of MARA Basin source Hoffmann 2007

1.6.2 Climate

1.6.2.1 Rainfall

A variety of air masses, altitudinal variations, influence the rainfall amounts and durations. The basin experiences a **bimodal rainfall pattern of wet and short rains**. The maximum precipitations begin in mid-March to June with a crest in April while the short rains happen between September and December.

The mean yearly precipitation ranges from between 1,000 mm to 1,750 mm on the Mau Hills, accompanied by highland mist of between 300-800 mm in the south. The northern and the western parts of the Mara Basin are the wettest, recording 1200 mm to 1800 mm per annum. The rainfall at Narok Town, is 1016 mm per annum.

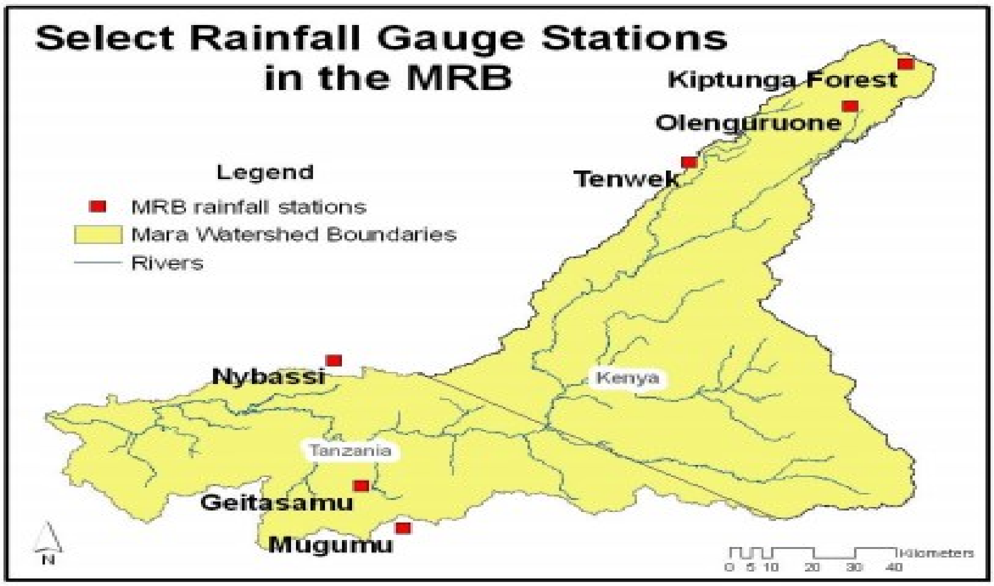

Figure 1:6 select Rainfall gauging stations in MRB source Hoffmann 2007

Figures 1.7 – 1.9 below show rainfall occurrence in selected stations within the MRB.

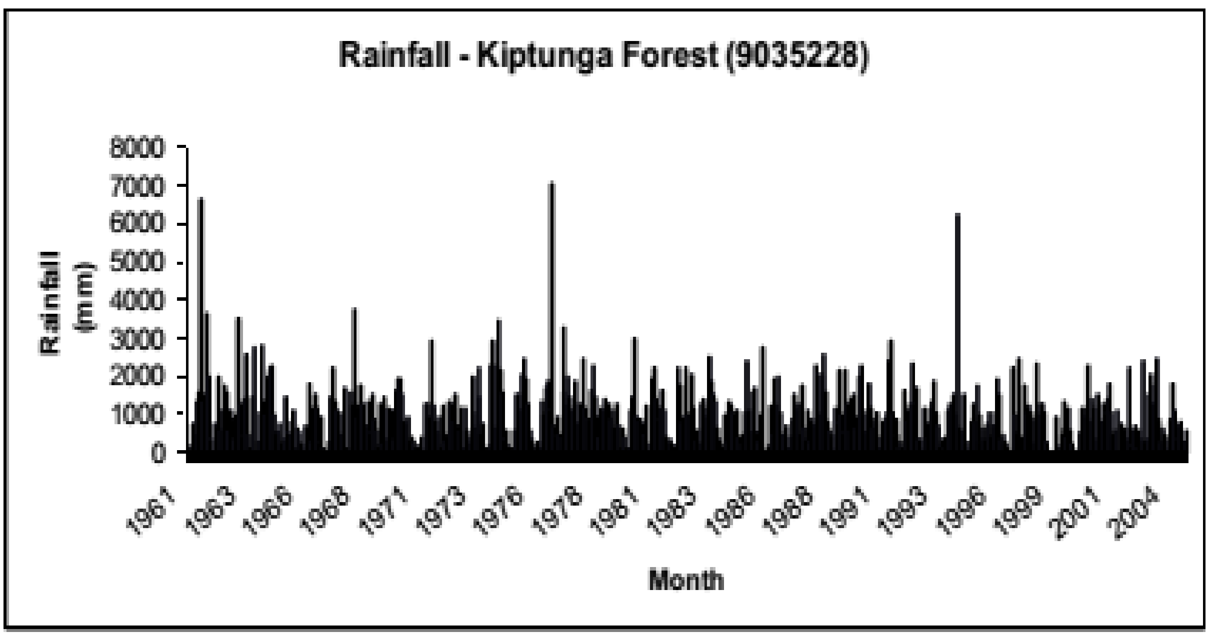

Figure 1:7 Monthly rainfall at Kiptunga Station 1961-2004

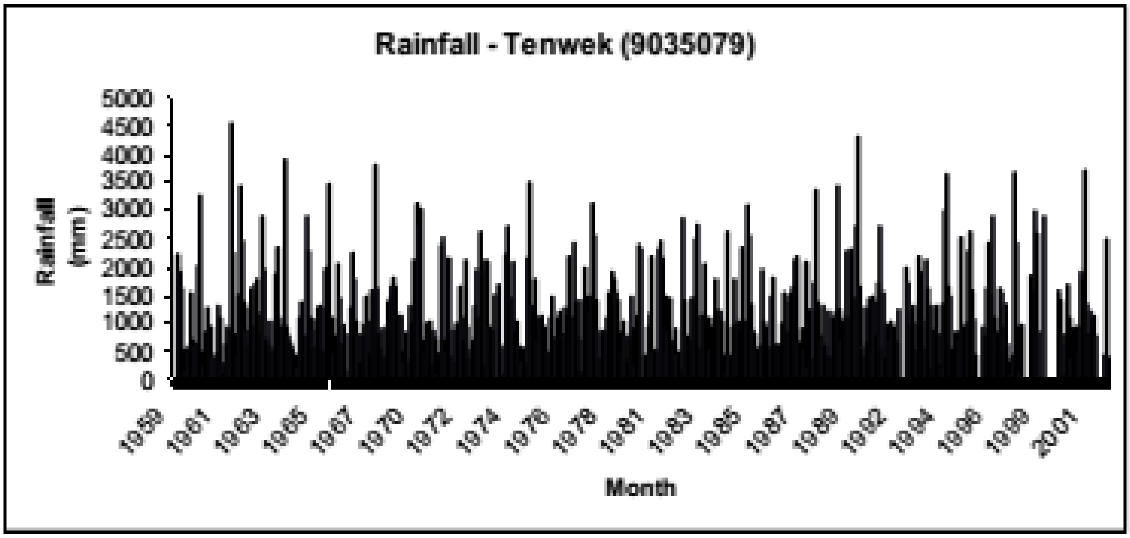

Figure 1:8 rainfall at Tenwek station 1959-2001 Source Hoffmann 2007

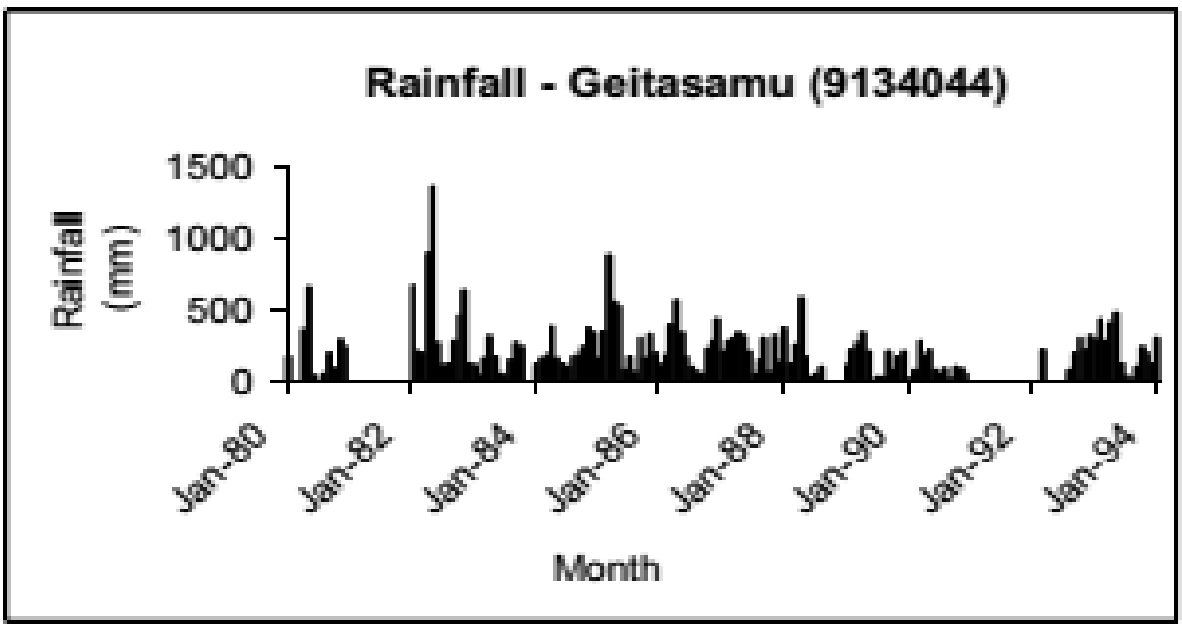

Figure 1:9 Monthly rainfall at Geitasamu station 1980-1994, Geitasamu Tanzania Source (Hoffman, 2007)

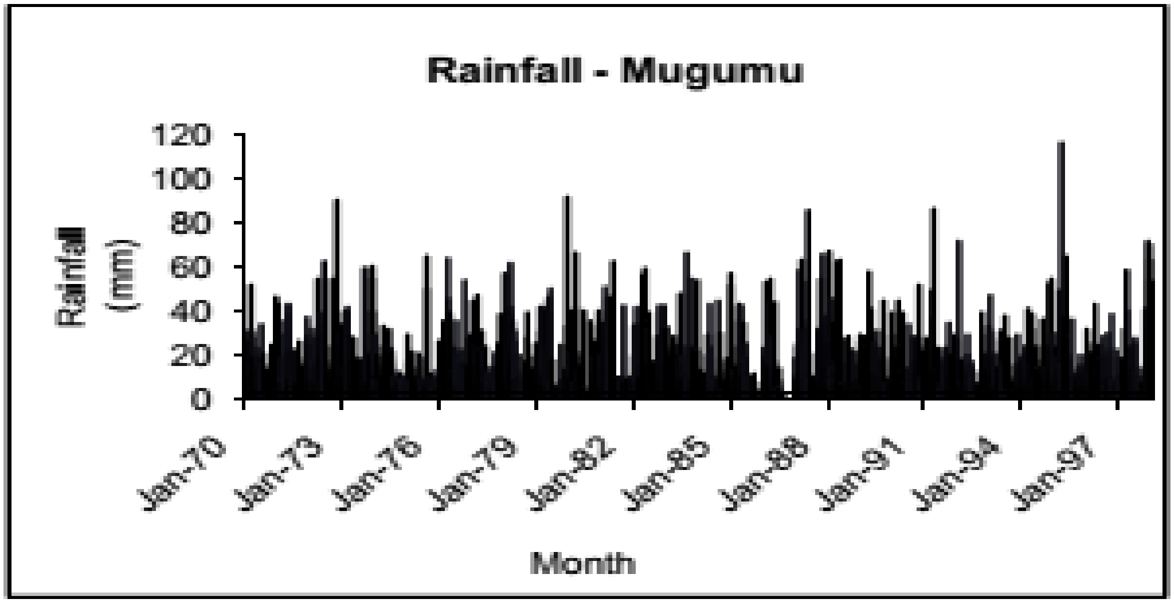

Figure 1:10 monthly rainfall at Mugumu Station 1970- 1997, Mugumu, Tanzania source Hoffmann 2007

1.6.2.2 Temperature and Evapotranspiration

The temperature is determined by altitudinal as well as rainfall variations, such that in elevated areas with high rainfall amount the temperatures drop to 10°C, while the lowlands in the central and southwestern parts the temperatures rise to 20°C. Temperatures are lowest in the wet months of March to May and the highest in the dry months of January and February. In general temperatures increase southwards and decrease northwards (Khordha,2005). *Figures 1.11* and *1.12* illustrate the temperature variation in the MRB.

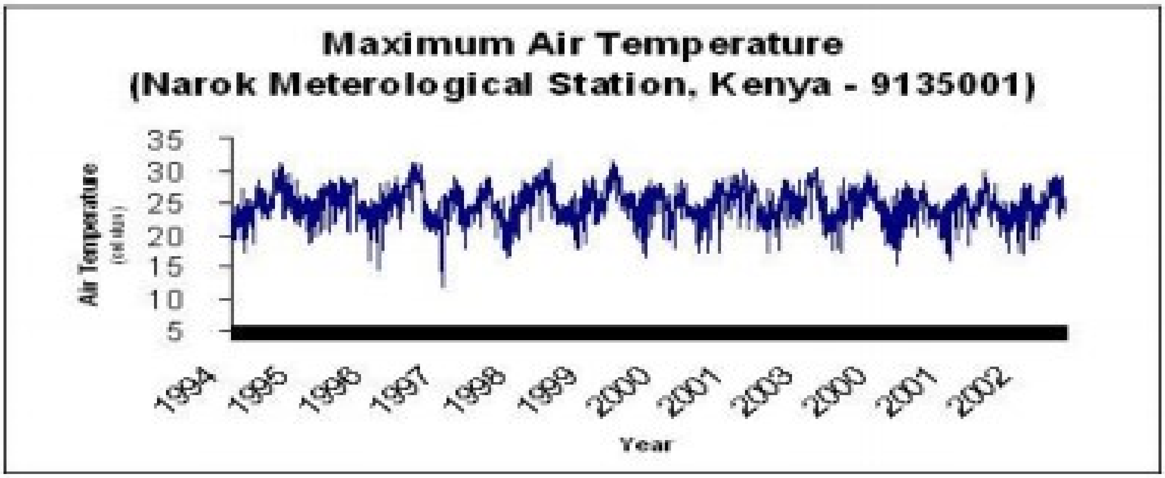

Figure1:11 maximum temperatures at Narok stations source Hoffmann 2007

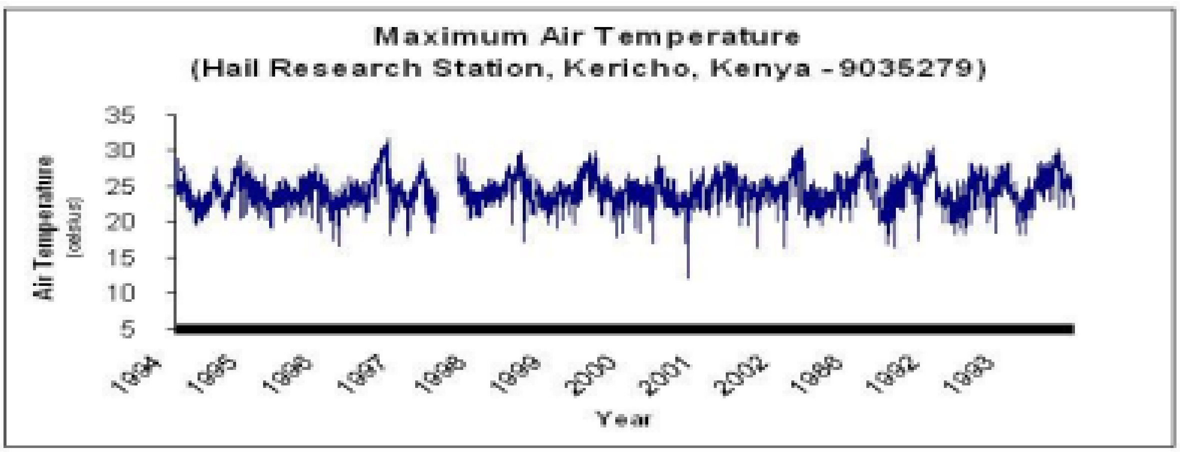

Figure1:12 Maximum temperature at Hail station (Hoffman, 2007)

1.6.2.3 Soils and Geology

The basin is covered by superficial deposits, quaternary lacustrine and fluviatile unconsolidated sediments overlie basement systems in parts of the basin (Krhoda, 2006). These results in the formation of good aquifers in the basin.

Soil distribution within the Mara basin is dependent on the geology and topography of the locality. The soil with Mara basin can be categorized into plain, swampy and mountainous soils. The rich volcanic soils in the mountain are sufficient for farm production such as zero grazing, barley farming and wheat farming. Although these soils are shallow, the soils located on the escarpments are well drained volcanic soils. Quartzite and muscovite-quartzite outcrops are surrounded by reddish brown sandy soils while black cotton soils are found over phonolites. On the remnant ridges, reddish brown gravels and sandy soils invariably formed from Basement complex rocks, grade into coarse scree as the outcrops are approached. The sheet floods from the flanking slopes exposes the soils to low fertility and disintegration. The alluvial sediments and silt along the Mara River have clogged the tributaries with sand after surges. Since the sandy bed gets blocked amid the wet season, Mara River is also referred as Sand River (Krhoda, 2006).

Dark-reddish brown soils that are shallow and excessively drained (lithosols and mollic andosols) are located on the minor escarpments and hills. They are not cultivated extensively hence are exposed to disintegration and processes of mass wasting; especially now since the thin soil cover is being disrupted by intrusive anthropogenic activities such as hill slope farming. The imperfectly drained soils ranging from grey to dark browns are located in plateau as well as Narosura, Siria and Niaragie Enkare high level plains. The Likirigi, Ol Punyuta swamps and the Mara river flood plains are populated by clay soils(eutric-flurisols). These soils are of moderate to high fertility (Krhoda, 2006).

1.6.3 Population and land use

1.6.3.1 Land use

The Mara Basin is a rich and diverse landscape. Towards the northern parts its habited by the Mau forest. This is also the origin of the two tributaries the Nyangores and Amala rivers. In this area the forest cover has been gradually reducing due to encroachment by the local inhabitants who practice small scale agriculture. Earlier studies by (Gereta, Wolanski, Borner, & Serneels, 2002) , based on satellite imagery posited that the forest cover has reduced from 752 square kilometres in 1973 to 493 KM^2 in 2000.

A study by (Ottichilo, Leeuw, Skidmore, H.T, & Said, 2000), noted that south of the Mau forests the land is increasingly being converted for agricultural and settlement usage. This is evident by the presence of huge tea plantations and the expansion of major settlements such as Bomet, Tenwek hospital and the Mulot trading centre.

Towards the Maasai Mara National reserve, and in areas near the Serengeti national park the land is majorly utilized in group ranches. Large scale wheat farming is practiced on the Loita plains.

1.6.3.2 Industry

Buhema and North Mara Mines are two mining sites present within the lower part of the Mara basin. The Buhema mines operation was suspended in 2009. The North Mara Mines (NMM) are the ones currently in use hence extract water from the mara river for its operations. It's expected that the water demand from the mines will increase due to the expansion of the facilities.

Meremeta is a state-owned company that operates the Buhema Mine, located near the border of the MRB, approximately 47 km southeast of Musoma (Yager, 2004). Buhema is an open pit/carbon-in-leach mining operation that began operation in February 2003 with an expected life span of eight years (Yager, 2004). Through 2004, Buhema's monthly production amounted to between 240 and 250 kilograms of gold from approximately 100,000 metric tons of ore, with future increases in ore production expected (Yager, 2004).

The second gold mining operation within the MRB is the North Mara Mine (NMM), run by Barrick Gold Corporation of Canada. The NMM is located just over ten km south of the Kenyan border in western Tanzania (Tarime District), approximately twenty km west of the SNP (NMM, 2006).

Originally, the mine started production in September of 2002 under East African Gold Mines Ltd. before being purchased by Placer Dome Gold Inc. of Canada in July of 2003. Barrick Gold Corporation took over NMM in early 2006, which encompasses the Gokona, Nyabigena and Nyabirama (Rama) pits. This open pit gold mining operation produced 6,485 kilograms of gold from approximately 2,130,000 ones of ore in 2004, with expected increases in gold production from 2.13 Mt/yr. to 2.8 Mt/yr. in 2005 due to the expansion of ore treatment capacity in 2005 (Yager, 2004).

1.6.3.3 Population

The Mara basin transcends both rural and urban centres and has a diverse mix of the locals. Population within the basin has grown from less than 300,000 people in 1989 to almost 1,000,000 people according to the recent estimates. This can be attributed to the vast fallow lands available and the new economic opportunities that are brought about by the various developments that are springing around the main economic mainstay of tourism.

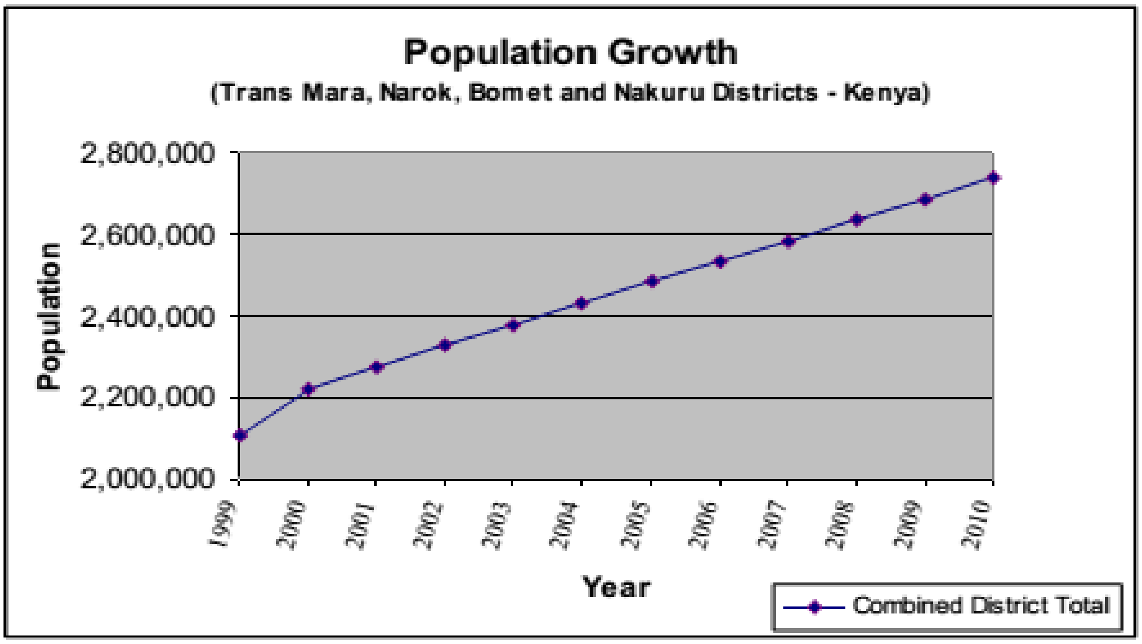

Figure1:13 Population growth within the MRB source KNBS 2006, Adapted from Hoffmann 2007

Chapter Two: LITERATURE REVIEW

2.1 Introduction

According to Cap-Net, (2005) the integrated water resources management framework is a methodical approach that supports sustainability in terms of water development, allocation and monitoring within the objective spheres of societal change, economic and environmental change. In a study done by Akivaga (Akivanga, Otieno, Kipkorir, Kibiiy, & S, 2010), He posits that solutions regarding water use, allocation, development and sustainability can be confusing hence the need for clarity in making such decisions.

Increasing global water scarcity has lent increasing importance to water allocation plans and agreements in resolving international and local conflicts over water accessibility. Despite the objective and approach evolutions, the basic fundamental concept of allocation still is the determination water available and its equitable sharing amongst competing uses and users (R. Speed et al 2003).

Various challenges such as increase in abstractions, decrease of available water infrastructure sites, climate change and declining fresh water levels has led to focused optimization of the available resources nearing in mind the economic social and environmental significances and the existing trade-offs within given dynamics.

The complexity of balancing the given factors in different scenarios and the resultant implications, response anchored scenarios on climate change, water pricing incentives, shifting economies. Recent approaches to this quagmire are spurred by the meshing of the following criteria;

- a comprehension of the significance of water and the demand of water stakeholders,
- environmental flow assessments,
- a right balance between the rights to take water and the protection of the environment.

Sufficient grounding in the above provides greater flexibility in the manner water is allocated in response to the emergent and emerging issues.

2.2 Integrated water resources management

According to a report by the global water project (2000) this an approach of coordinated management and development of resources (water, minerals, and land) so as to optimize the consequent social and economic gain in an equitable way without depleting the existing critical ecosystems.

Currently, Kenya has found WRMA a critical platform in the implementation of water sector reforms. The developed policy model is aimed at coordinating stakeholders in process of managing and allocating water resources. The framework has undertaken scientific approach of demonstrating the existing scenario caused by various development of resources and alteration in supply conditions, thus, assisting water managers to make critical decision at the catchment level.

2.3 Water Balance

Water availability in a catchment is best realized through appreciation of the hydrologic cycle concept. Onyando (2000) and Gamble et al. (nd) assumed that the concept outlines the hydrological flow in various states through the atmosphere and the terrestrial settings.

Exchanges between different stages of the cycle involve evaporation and transpiration from the land and water bodies, condensation in the atmosphere to form clouds, precipitation from the atmosphere, infiltration and percolation to form groundwater and runoff on the land surface (Onyando, 2000). Water managers can utilize the hydrological cycle to understand transformation of water at various paths and the quality and quantity of the transformed water at differed states of the cycle (Gamble et al., n.d).

The concept of hydrological cycle assist hydrologist with a run-off instrument to assess the health of stream and evaluate source control besides evaluating environmental impacts in watercourses (Hussain *et al*., 2011). Onyando (2000) and Odira,et al. (2010) have noted that lumped watershed, distributed and semi distributted Rainfall-Runoff models can outline issues ralted to hydrological processes.

The watershed model demands physiographic data such as the channel work configuration, slope and length of the channel, positioning of the drainage divines and the sub-catchment. The Digital Elevation Model (DEMS) and Geographical information system (GIS) availed technological advancement which have resulted to extensive application of DEMs in hydrological research, and environmental investigation (Odira, Nyadawa, Ndwallah, A, & Obiero, 2010).

Water resource managers are faced with three basic challenges namely shortage, surplus and quality among other sophisticated mixture of cultural, engineering and physical aspects.

The water budget strategy to management of water resources generates the concepts of water surplus and shortages. The water budget strategy presents the net available water at any location as a function precipitation gain, evapotranspiration loss, soil moisture gains or loss, and loss or gain from other man made functions (Gamble *et al*., n.d). A water budget is expressed in the following equation (Gamble *et al*.):

$$W = P - EvT \pm Sm \pm Hmis \pm P$$

Where;

W= Available Water
Sm = Soil Moisture
P=Rainfall
Evt= Evapotranspiration
Hmisc = other man made functions

The water-balance model outlines the distribution of water among different dimensions of the hydrological system at various time intervals (McCabe and Markstrom, 2007).

2.3.1 Water availability within the Mara Basin

Recent water availability studies conducted in the basin (Dessu, Melesse, & Bhat, 2013; Dessu & Melesse, 2012; Majule A. E., 2010; Hoffman, 2007; Gereta, Wolanski, Borner, & Serneels, 2002; Gereta, Wolanski, Makus, & Serneels, 2001) posit that climate change, various economic activities, increasing human population and settlements and water pollution and increased water abstraction are challenges altering the natural hydrologic regime of the Mara river.

In a study done in 2008,(Mati, et al., 2008) reported that Mara river is experiencing increasing low flows during dry periods and increasing peak flows during the wet season.

The movement of the ITCZ is a major driving factor that influences the hydrology of the MRB. Rainfall runoff studies conducted by Dessu and Melesse (2013) showed that the rainfall varies within the basin and that the two rivers Nyangores and Amala are critical during the dry period as they provide the resident flows. Climate impact studies (Dessu, Melesse, & Bhat, 2013) conducted using General Circulation Models (GCM) show that the basin will experience increase in annual river volume and rainfall amounts. However other studies depict drier dry seasons and wetter rainy seasons.

Water losses within the basin can be attributed to evapotranspiration losses that account for 75% of losses within the basin.

2.4 Water Allocation and Abstraction

Water abstraction for various uses from any source changes the flow regime from the natural state (Wisser, Douglas, Schumann, & Vörösmarty, (2007; Schofield, Burt, & Connell, 2003). Competing water uses in the river basins provide an ever evolving challenge to water managers and policy makers in regard to equitable and sustainable water allocation, a factor that is compounded more by rapid land use changes and climate variability.

Basin wide computational models maybe of aid in the mapping of economic and physical impacts/influences over time and space. In (Cutlac & Horbulyk, 2011), they posit that these models can provide insights into current effects and forecast future possible scenarios given existing or revised parameter changes in regards to policy.

Increasing water scarcity in the face of competing water uses influences water allocation necessitating a priority allocation mechanism. This comes into force when the complete water rights of the users cannot be met. A prioritized system gives water managers control in a river basin and enables them to give preference based on regional or national objectives (United Nations, 2000).

However, the above mechanism does not give effective result given that it is unable to enforce efficient water use, lacks an incentive mechanism and is open to outside influences such as political influence and unclear decision making on inter sectoral allocations and pricing mechanisms (Weragala, 2010).

In a study carried out in the northern California wine country, it was noted that abstractions of water from rivers fundamentally alters stream ecosystems. In the study, analyses of seasonal water demand, which described the fine-scale means through which needs were met, illustrated that direct abstractions from streams caused stream flows to drop by more than 90% locally, and also affecting downstream areas (Dietch, G, & A.M, 2008).

2.4.1 Water Demand

Water demand management is a practical approach the advances the efficient, unbiased and effective utilization of water and is installed with economic, technical, financial, administrative and social functions that increase the resilience to water systems to enable the approach to adopt to water shortage (Bhatti and Nasu, 2010). Water resource planning and management is becoming increasingly challenging to resource managers and professionals (Sharifi 2002) partly due to drastic increase in population, technological advancement and economic growth (Bhatti and Nasu 2010). Competition between various water users and uses has intensified coupled with intensive land uses in watershed that have caused degradation of water quality and contamination of sources of supply that result in significant depletion of surface flows. Enforcement of new environmental laws further places constraints on the use of surface and ground water supply (Sharifi, 2002).

2.4.1.1 Water demand in the Mara Basin

The Water Resources Management Authority through its regional offices at Kisumu and the sub regional offices at Kericho hold brief on the water use details in form of permits and abstraction permits for activities currently on going on Kenyan catchment regions. In this study the above resources were utilized to estimate the current demands within the basin for the current accounts and reference scenario. Population estimates based on the 2009 national census KNBS estimates on urban and rural dwelling residents was used to estimate the demand.

Wildlife population was based on earlier studies (Kiambi et al.,2012; Ogutu et al., 2011) while the water consumption rates were based on the rates suggested by (King, 1983). Increase in land use change was also considered as more local Maasai residents are shifting from pastoralism to farming activities.

This study focused on consumptive water uses. The following water demands were modified from the earlier demands by Hoffmann (2007). The simulated sectoral water uses/demands are;

- Irrigation,
- Human Consumption,
- Animal Needs (Domesticated + Wildlife),
- Tourism and Industrial Demands.

Human Consumption

The Mara river provides the water life line to all activities and livelihoods within the basin. Previous studies estimate that more than 50 % of MRB residents in Kenya collect water directly from the Mara River or its tributaries and 5% collect rain water while 20% get water from wells and springs for drinking. Bomet, Bureti and Narok residents satisfy their water needs almost exclusively from surface water sources, about 80% of their needs (Dessu, Melesse, & Bhat, 2013).

On the Tanzanian side the domestic water supply is assumed to be covered at 80% by surface water sources. Results from previous studies in the basin indicate that compared to groundwater sources, surface water resources are the main drinking water sources in the basin.

Irrigation

Irrigation is practiced in various parts of the basin at both small scale and large scale. The upper and lower areas of the basin are under household small hold subsistence cultivation practices, while large scale irrigation farms are distributed along the river.

Previous studies Nile Basin Initiative, 2004; Onjala, 2004, show that there is considerable potential for irrigation agriculture within the basin and that in recent years the acreage under irrigation has really increased. Recent initiatives such as the proposed small holder irrigation schemes within the Tarime district of Tanzania will definitely increase the pressure on the water resources available. With this increase has come a surge also in the increase of water needed for crop husbandry.

While irrigation timeframe and quantities vary with rainfall, it is estimated that land under irrigation uses approximately five to seven mm of water per day as estimated by Tarquin Wood of Olerai Limited Mara Farm (**adopted from MRBWWAP,2013**), to satisfy the crops consumptive use (evapotranspiration) requirements.

Irrigation water demand data was obtained from previous studies (Sinclair 1995, ESA 2008, RKNBS-IHBS 2007. (URT-NSCA-Mara, 2012; Dessu, Melesse, & Bhat, 2013) The irrigation water demands were lumped together to estimate the total demand within the MRB.

Industry

Water demand by the mines present within the MRB was classified as an industrial demand. In the MRB there exists two mining sites, the Buhemba and the North Mara Mines. They are located at the lower edges of the MRB, in the Tanzanian section of the basin.

Recent studies (Majule A. E., 2010) show that the major industrial user in the basin is the NMM. (Majule A. E., 2010), reported that the NMM extracted a daily average of 3200 cubic metres and had a recycling rate of 60% within its production system. It also harvests overland flows during the rainy season (URT-NSCA-Mara, 2012). The NMM have an annual permit to withdraw 1.5 million cubic metres.

The NMM do not abstract during the months of September and December due to low water levels (NMM,2006). For this study the water demand utilized was the maximum allowed by the permit.

Tourism

In recent years the number of tourists visiting the MRB has been increasing. Recent numbers increased from 133,000 visitors in 1995 to 240,000 in 2004 in the Maasai Mara National Reserve and from 59,564 visitors in 1990 to 378,218 in 2002 in the Serengeti National Park (Kenya NBS, 2005 and Tanzania NBS, 2002). The main attraction is usually the annual wildebeest migration that begins during the dry season around June - July (Gereta, Wolanski, Borner, & Serneels, 2002) as they through the SNP move into the MMNR in search of food. With the river flows already low, a combined increase of wildlife and tourists puts more strain on the limited waters in the river.
An inventory of the lodges nd hotels capacity and demands done by Hoffmann (2007) was adopted in estimating the water demand for the tourism demand node. Some of the parameters that were used included total bed capacity, monthly occupancy rates and water use per day.
The water uses per day of a person staying in a luxury camp, non-residential was taken from the Water Systems Design Manual, 2001, that gives a range of 380 to 570 litres per person per day. For the model utilized herein, I used 380lpd. Table 1 below shows average monthly bed occupancy at the game lodges within the MRB.

Month	Bed occupancy rate	Beds occupied of the total (2116)
Jan	50	1058
Feb	58	1228
March	47	995
Apr	43.5	921
May	32.5	688
Jun	50	1058
Jul	66	1397
Aug	77	1630
Sep	57.5	1217
Oct	55	1164
Nov	42.5	899
Dec	45	953

Table 1 Bed occupancy rates in the MRB source Hoffmann 2007

Wildlife and animal demand

1. Livestock demand

The population of domesticated animals within the MRB shows an increasing trend more specifically the cows and goats while sheep population showed a slight decline within the periods 1984,1998 and 2000 census data. Recent census data on the Kenyan side of the MRB is illustrated as shown in table 2 below.

	Molo	Narok north	Narok south	Trans mara	Bomet
Cattle	182,243	255,881	701,889	459,106	210,855
Sheep	149906	529,492	935,757	184,780	53060
Goats	37724	219394	510328	150496	82395
Camels	2	116	449	43	5

Donkeys	20208	38796	38934	20466	18363
Pigs	1789	3959	2275	1097	604
Chicken	439209	113328	172644	275347	364644
Bee hives	64052	19402	22730	22335	14807

Table 2 Domestic animal population Kenyan side of the MRB Source KNBS 2010

The population of livestock on the Tanzanian side was based on estimates done by Hoffmann 2007, as illustrated in the table below;

District	Cattle	Shoats	Donkeys
Musoma	115573	56162	963
Serengeti	109307	117459	308
Tarime	84959	35082	253

Table 3 livestock population in Tanzania part of MRB source Hoffman 2007

For the estimation of demand the following daily water demand for livestock built on findings by King 1983, were utilised.

Species	**Weight (KG)**	**Daily drinking requirement**	
		Mean devp(litres).	**Guidelines for**
Zebu	350	16.4	25
Goat	30	2.0	5.0
Sheep	35	1.9	5.0
Donkey	120	12.4	15

Table 4Daily Water requirements domestic animals Source (King, 1983)

The water demand per ditrict within the basin is illustrated in the tables below; the figures are based on the year 2010.

Kenya

District	Water amount (m^3/year)
Bomet	1,658,409
Molo	444,365
Narok South	5,276,540
Trans Mara	1,473,985
Total	**8,853,296**

Table 5 Water Demand per district in Kenya Source MRBWAP 2013

DISTRICT	Volume (m^3/year)
Musoma	1,162,372
Serengeti	1,213,475
Tarime	840,660.7
Total	**3216508**

Table 6 Water demand in the Tanzanian Side of the MRB Source MRBWAP 2013

2. Wildlife demand

The MRB economy is based on the wildlife. These faunas ensure that activities like tourism flourish hence a chain like reaction to their presence in terms of monetary exchanges from luxury lodges to local tour guides and the local inhabitants.

The Mara river is the lifeline of these majestic creatures as it's the only source of water utilized especially during the dry season. Recent studies (Mduma, Sinclair, & Hilborn, 1999) noted that these populations especially the herbivores are limited by water availability and forage mostly during the drought years. Such occurrences result in population drops. Gereta et al,2002 postulated that 30% of the wildlife population will be wiped out if the Mara River Was to run dry.

It's also important to note that the all year around migration of wildlife due to seasons also contribute to the wildlife demand (Hoffman, 2007). Earlier studies (Wolanski et al, 1999; Gereta et al,.2002; Musiega et al,.2004) estimate that the movement of about two million heads of wildlife move from the Serengeti plains towards the MMNR to drink water from the Mara river during the dry season. The migration is estimated to last four months.

As a result of the complex movement of the wild animals, previous studies (Hoffman, 2007; The East African Community, 2013) done to estimate the wildlife demand all year around, the demand is split into two the annual migration demand and the resident demand which are then summed up to give an estimate of the wildlife demand.

In this study the findings for wildlife demand calculation ware adapted from studies done by Hoffmann 2007, while Daily water requirements was modified from duToit (2002). Although the rates of water consumption differ according to species, consumption is significantly correlated to body weight of each livestock (Peden, Alemayehu, & Amede, 2009). The water requirements are projected at 4% of the adult weight.

Animal	Population (Year 2000)	Individual daily water requirements (litres)
Buffalo	4733	31
Eland	1025	23
Elephant	989	150
Grant's gazelle	13353	2.6
Thomson gazelle	32880	1
Maasai giraffe	2213	40
Impala	36929	2.5
Hartebeest	1295	5.5
Topi	6244	5
Warthog	1889	3.5
Waterbuck	143	9
Wildebeest	88256	7
Burchel zebra	43624	12

Table 7 selected daily water requirements adapted from Du Toit 2002, UNEP 2002

2.4.2 Water allocation policy

Improved water resource policies are obligatory to among other things facilitate efficient inter sectoral allocation of water and reverse degradation of catchment areas such water quality, irrigated land base and watershed. However, the structure and design of distributive reform policy are less understood particularly in developing regions (Cai, Ringler, & Rosegran, 2006). The existing hydrological structures and legal frameworks affects the dimensions of any system of water allocation. Therefore, certain kind of distribution are demand certain set of regulation, laws, institutions and hydrological structure to function effectively (Dinar, Rosegrant, & Meinzen-Dick, 1997). The approach for distributing water can be defined by various kinds of allocation, varying from total government control to predominantly market allocation, to a government allocation and a mixture of market (Meinzen- Dick and Mendoza, 1996).

The most used model to allocate water resources is the quantity based administrative allocation model (Meinzen-Dick and Mendoza, 1996). Particularly, the model ensured sufficient allocation of home-use water, irrigation supply and the needs for the ecosystem as well as improving food security, environmental health and public sanitation. Dinar, Rosegrant, and Meinzen-Dick (1997) consider public allocation to have various purposes and principally connected to satisfaction, equity and sovereignty of greater public good.

Water rights are key management instruments to improve water-use efficiency. Water rights can be perceived in terms of prior appropriative right, riparian rights and public allocation (Dinar, Rosegrant, & Meinzen-Dick, 1997; Zheng, Wang, Hu, & Malano, 2013). It has been argued that riparian rights and prior appropriative rights system are not fair to small users and non-riparian. Public allocation system on the other hand has been fronted as a correction mechanism, in which water is considered a state property and the government allocates water permits to users (Zheng, Wang, Hu, & Malano, 2013).

The harvesting of water from its natural reservoir either on the surface or sub surface need to be sustainable without harmful effects to the environment. The Environmental Agency (2007), establishes that regulation on the manner, place and amount of water abstracted can be achieved through a permitting system. Kenya has achieved this through the Water Act of 2002 and the WRMA water rules of 2007. The above legislation provides a framework where abstraction licenses are sought and given within some set criteria (Muthike, March 2007).

2.5 Decision Support Systems for Water Management

Water is increasingly being viewed as a valuable economic good. Its principal versatile use in various sectors contributing immensely to this notion. Being such an important input, various mechanisms have risen up to ensure that there are adequate water resources to meet specific objectives. However, in an increasingly changing environment, the need to maximize the limited available water has given rise to measures aimed at ensuring prioritized areas have their needs met.

It is in this regard that programs and methodologies were developed to be utilized in conjunction with stakeholder participation to arrive at a safe yield utilization of a resource while ensuring its sustainability.

Emphasis is usually given on the hydrological model coupled with environmental assessment with socio-economic evaluation. These three pillars help ensure that equitable and sustainable decisions are made. Moreover, the simulations therein, help provide a compromise from the different actors as their views will be taken in and the possible results given. In this regard, the DSS acts as a bridge between policy makers, scientists and the other stakeholders.

There exists several DSS programs. These are made specifically orientated to given river basins or geographical conditions. Others are made generically and can be adapted to various river basins and geographic areas inclusive of stake holder involvement and simulation capability. Some of these programs are;

i. Mike basin
ii. Mike Hydro Basin
iii. Mike SHE
iv. WEAP
v. RIBASIM

2.5.1 Mike Basin

MIKE BASIN is developed for use by the Danish Hydraulic Institute. It is a multi-purpose planning and management DSS. It is a network based model. A feature that is used to represent the streams and rivers found within the basin. It focuses mostly on water quality modelling, reservoir operations, water allocations and conjunctive water uses. Its building blocks are the utility/water usage nodes such as the irrigation node, hydro power nodes, water demand nodes.

It couples the uses of GIS through ArcGIS and hydrologic modelling to provide basin wide solutions. MIKE BASIN is a quasi-steady-state balance model. It also allows for routed river flows. In simulating ground water, the model utilizes the linear reservoir equation while water quality is based on the advection transport (http://www.dhisoftware.com/mikebasin/).

The model has been utilized in various projects in countries such as Peru, Zambia, Tanzania, Poland and also in the USA (states of Idaho and N. Carolina). In Thailand, the model was applied to the Mun river basin located on the north eastern part of the country. It was used to access the water availability and utilization. The study drew conclusions that there was limited dry season demand than wet season demand. These findings formed a basis for policy formulation with regards to water allocation within the basin.

2.5.2 RIBASIM

The river basin simulation model (RIBASIM) is a model utilized for river basin behaviour analysis under various hydrological scenarios. It simulates the water balance within a basin and can be used to illustrate the water balance at any given location in the basin. It can be utilized to simulate demand management, operational and infrastructure related measures. It gives a representation of water distribution within a study site while giving detailed results on water quality and sedimentation analysis within a river or reservoir.

Flow routing within the model is on a daily time step. Moreover, the availability of various routing methods such as; the Manning formula, flow-level relation,2-layered multi segmented Muskingum formula, Puls and the Laurenson non-linear “lag and route” method. The comparison and evaluation of scenarios is done through the Case Analysis Tool (CAT) (http://www.wldelft.nl/soft/ribasim/int/index.htm).

RIBASIM has been applied in various countries, projects and situations. A recent case is when the model was applied in the Flood Early Warning System (Delft-FEWS) as a flow routing component.

2.5.3 MIKE SHE

MIKE SHE is a comprehensive numerical modelling system, an integrated hydrological model that simulates flow on the land based on the hydrological cycle. Processes such as overland flow, infiltration, evaporation and ground water flow is also simulated. The model can be summed up as an integrated, fully distributed, physically based and a modular model. (http://www.crwr.utexas.edu/gis/gishyd98/dhi/mikeshe/Mshemain.htm)

MIKE SHE has been used in various studies and on various scales. The scales vary from basin wide focus to narrow specific problem on small scales. Studies that focus on surface and groundwater conjunctive use, domestic and industrial water consumption, wetland dynamic studies and water quality simulations can also be carried out using MIKE SHE.

2.5.4 Mike Hydro Basin

Mike Hydro Basin as a DSS within the IWRM framework is an easy to use model. It is a multi-purpose, map based DSS. Mike Basin Hydro is a versatile and powerful tool. It's a conceptual model. It is designed for application from the global scale to local scale with regard to water analysis and equitable allocation. The diverse pool of tools such as; **catchment and river delineation tools, catchment rainfall run-off calculations, water allocation, water use analysis from different users and water quality modelling using ECO lab.** The above features are made more easy to use due to the ease of use managed through the graphical user interface. (https://www.mikepoweredbydhi.com/products/mike-hydro-basin).

2.5.5 WEAP

WEAP is a user-friendly software tool that takes an integrated water resources management approach to water resources management and planning and policy analysis (Loucks, 2008, Sieber and Purkey, 2011). It aims at assisting decision makers in storing and managing water demand, water availability, waste generation and water cost and in evaluating water development and management options (Van Loon & Droogers, 2006).

WEAP incorporates water supply in the context of demand-side management, and water quality and ecosystem preservation and protection into a practical tool for water resources planning and policy analysis (Sieber & Purkey, 2011). The model places demand-side issues such as water use patterns, equipment efficiencies, reuse strategies, costs, and water allocation schemes on an equal footing with supply-side themes such as stream flow, groundwater resources, reservoirs and water transfers. (Van Loon & Droogers, 2006; Yates, Sieber, & Purkey, 2005).

WEAP is distinguished by its integrated approach to simulating both the natural and engineered components e.g. reservoirs, groundwater pumping maintaining water demand and supply information of water systems, allowing the planners access to a more comprehensive view of the broad range of factors that must be considered in managing water resources for present and future use (Sieber & Purkey, 2011).

Model objects and procedures introduced can be utilized to analyse a diverse range of issues such as climate variability, watershed conditions, anticipated demands and ecosystem needs, available infrastructures and operational objectives in a transparent manner (Yates, 2005). The result is an effective tool for examining alternative water development and management options. WEAP21 is developed by the Stockholm Environmental institute (SEI).

Chapter Three: Methodology

3.1 Introduction

This chapter discusses the methods and tools utilized in this study.

The *Fig*ure below shows the conceptual framework embraced in this study.

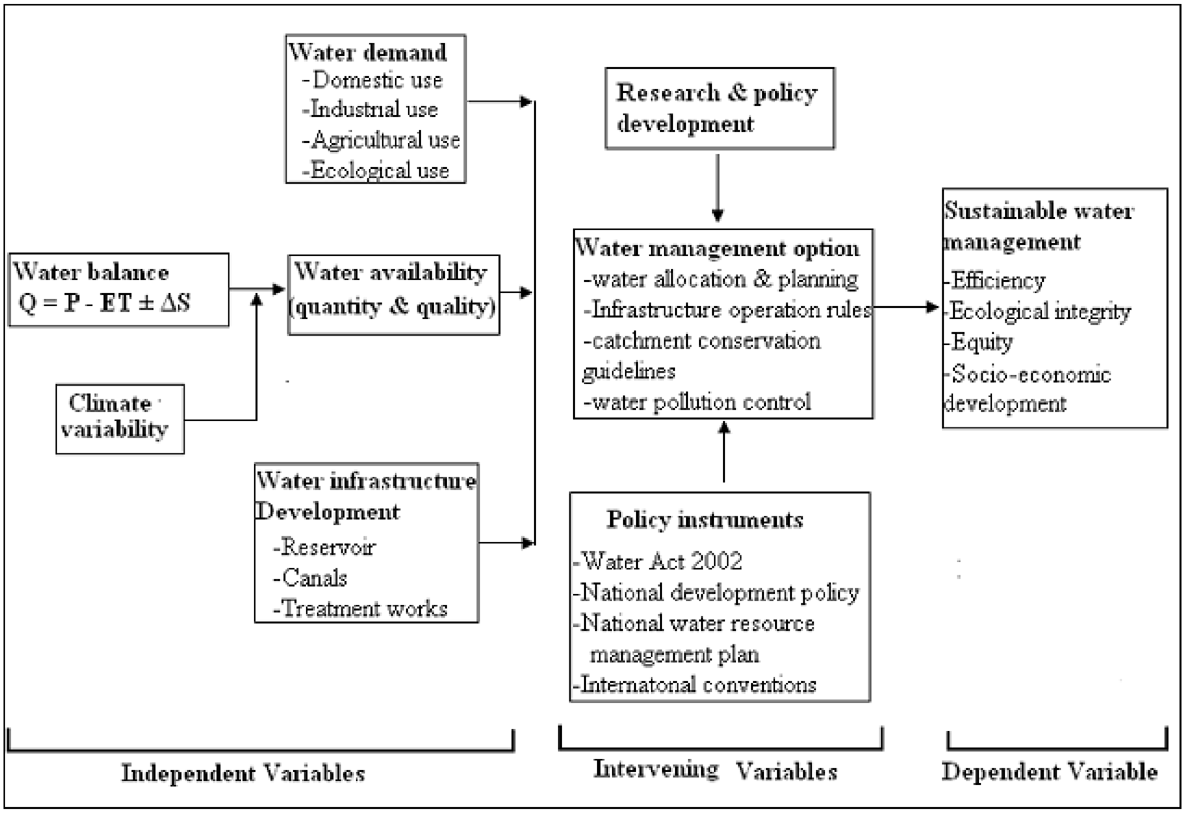

Figure3:1 Conceptual framework

3.2 Research Design

This study obtained data both from primary and secondary sources. Secondary data was obtained from desktop reviews of available secondary literature, databases and government documents. Hydrological data was obtained by from the Water resources management authority.

3.3 Data collection

The study targeted the water abstractors from the Mara River and its tributaries within the basin. Total sampling was used due to the small number of abstractors in the basin. The study focused on abstractors with authorization, permits and illegal abstractors for domestic, industrial and commercial purposes. Structured questionnaire interviews were used to gather quantitative primary data on water abstraction. The study aimed at gathering information on the number and amount of abstractions, unit water use, compliance status with water rules and quantities of water abstracted for each class as defined by the Water Resource Management Rules of 2007 and specific use

Both primary and secondary data was collected in this study. The study utilized the permitting database held by the water resources management authority and the Mara River Water User Association to a certain abstraction details.

3.3.1 Primary data

SPATIAL DATA COLLECTION

A Digital Elevation Model (DEM) was downloaded from the internet. In addition, during the surveys in the catchment, GPS handheld receivers were used to georeference abstraction locations for all abstraction points for mapping purposes to indicate the spatial distribution of abstractors in the basin.

To determine the activity levels of production for scenario development, face to face questionnaire interviews were administered to enrich the primary data collected from all the abstraction points in the basin. The questionnaires had both structured and semi structured questions to obtain more information from the identified abstractors.

3.3.2 Secondary data

Secondary data on historical discharges and/ or gauge heights and rating curves was obtained from WRMA data base. Daily rainfall, mean daily pan evaporation, daily minimum and maximum temperature and relative humidity records was collected from Kenya Meteorological Department (KMD) for all stations within and neighbouring the catchment.

3.4 Data analysis methods and presentation

Catchment and stream delineation using digital elevation model (DEM)

The DEM was pre-processed using ArcGIS 9.3 to derive the channel network, the location of drainage divides, channel length and slope, and sub-catchment geometry. The derived stream network was verified against digitized stream network from 1:50,000 topographic sheets of the same area.

3.4.1 Data Presentation

Data collected from the field was recorded and pre-processed in spreadsheets. Quantitative data was analysed using Microsoft Excel and results presented as charts and tables. Qualitative data was analysed based on the themes and sub themes.

ArcGIS 9.3 was used to process geospatial data to produce map overlays. Demand data analysis was carried out based on water abstraction data and water use analysis which will provide information on water use for all water uses.

Hydrological data was analysed for trends, low, medium and high flows and presented in charts. Surface water balance was presented by plotting the input and change in storage for each stream on a graph.

3.5 Model Calibration and Validation

The model calibration was undertaken using the PEST routine within the Model. It is a mathematical model that can perform a variety of functions such as; Interpretation (especially in geo- physical environments/models), Calibrations (adjust model parameters until the results yielded are similar to the observed in a natural/man-made environment).

Predictive Analysis, once a parameter set has been determined for which model behaviour matches system behaviour as well as possible, it is then reasonable to ask whether another parameter set exists which also results in reasonable simulation by the model of the system under study. The most important question is whether predictions made by the model with the new parameter set are different.

PEST is a nonlinear parameter estimator. PEST is a unique calibration tool in that it adapts to the model. The adjustment of sensitive parameters is done through trial and error in a bid to determine the best fit for a particular parameter or model.

PEST adjusts model parameters and until the fit between model outputs and field observations is optimized in the weighted least squares sense. PEST utilizes a nonlinear estimation technique; Gauss-Marquart-Levenberg method, which saves time by doing fewer model runs.

The optimized value of any adjusted parameter is within a 95% confidence range.
The observed discharge values at Nyangores 1LA03 were used to calibrate and validate the model. The calibration was done using the years 1972 – 1982. The result was then validated using values from the years 1990 – 2000.
The results shown in fig17 below shows that the model is able to predict the processes within the catchment.
The performance of the model was gauged using statistical means. These evaluation criteria were;

i. The Model Coefficient of Efficiency (EF) of Nash and Sutcliffe 1970
ii. The Mean Error (ME)
iii. The Mean Square Error (MSE)

The model efficiency coefficient EF of Nash and Sutcliffe (1970), is a dimensionless and scaled version of the MSE for which the values range between 0 and 1(1 for a perfect model) gives a much clearer evaluation of the model results and performance.

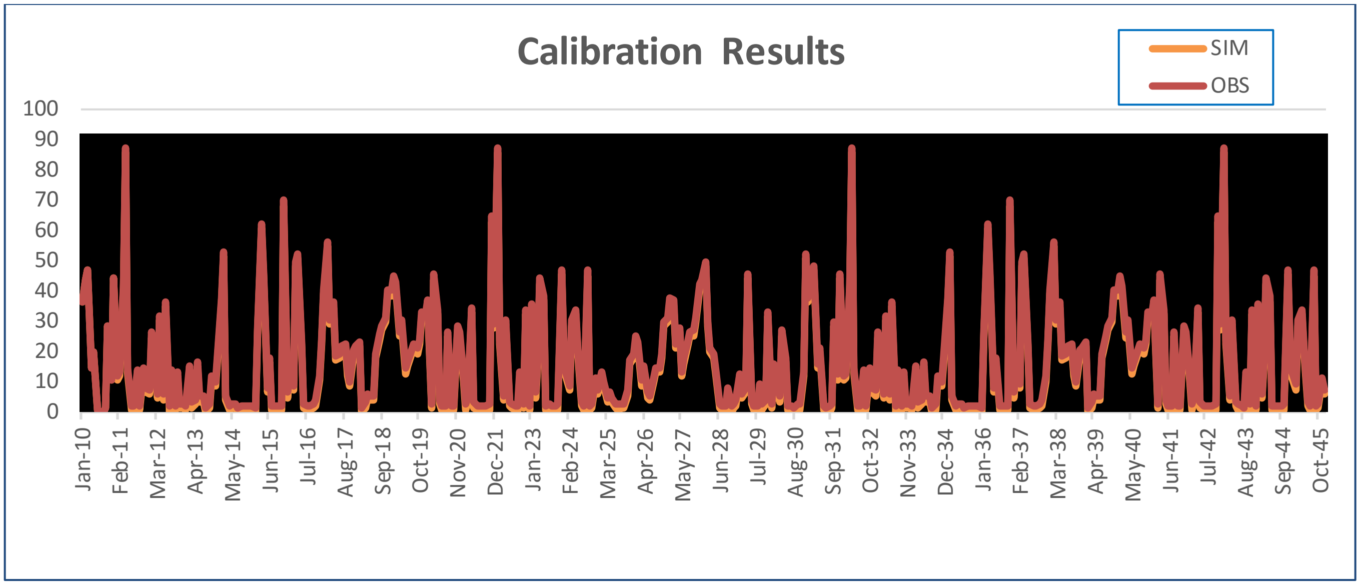

Figure3:2 Calibration chart results

Bias in the model is calculated using the ME while the MSE gives an indication of the random error after correction. The calibration results are included in appendix 2.

The result of model calibration and validation are given in the table below;

EF	0.992683	
R^2 (Validation)	0.9998	
RMSE	30.26978	M3/S
BIAS	-1.43585	M3/S
ABS BIAS	1.435849	
ABS LOG BIAS	0.229163	

Table 8 Results of calibration and validation

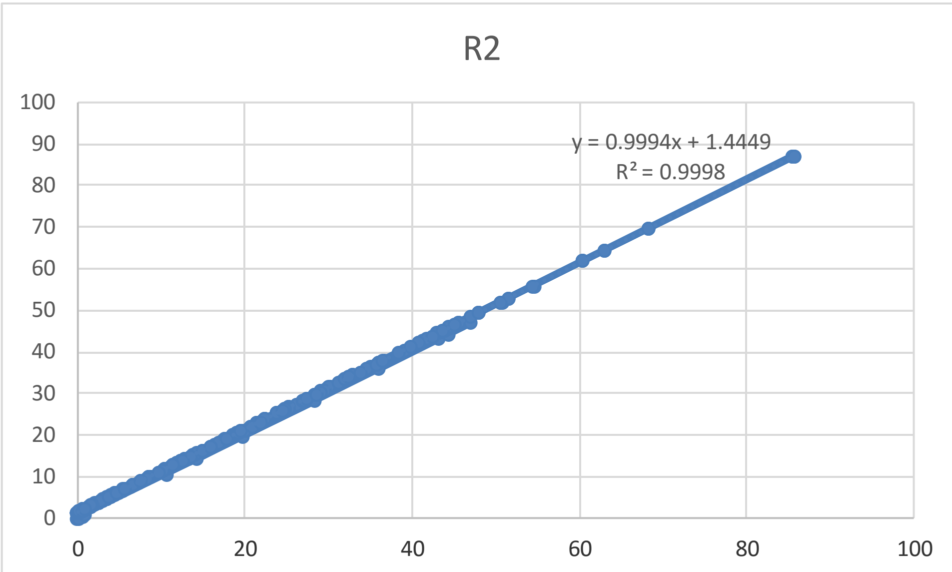

Figure3:3 showing a chart of R squared

$$ME = \sum_{i=1}^{N} = \frac{Q_s(i) - Q_{0(i)}}{N}$$

$$MSE = \Sigma_{i=1}^{N} = \left(\frac{Q_s(i) - Q_0(i)}{N}\right)^2$$

$$EF = 1 - \left(\frac{MSE}{s_{Q_0}^2}\right)$$

Where;

N = number of data points

S= variance

Qs = simulated flows

Qo = observed flows

EF = Model efficiency

3.6 Scenarios Development

Scenarios can be defined as sets of assumptions or alternative mechanisms (policies, pricing and demand management strategies) that form the basis of a projection. Therefore, Scenarios are self-consistent story-lines of how a future system might evolve over time in a particular socio-economic setting and under a particular set of policy and technology conditions (Yates, Sieber, & Purkey, 2005).

Through scenario analysis, the posed question" what if" is answered. Moreover, it enables the poser to change and test the limits of endurance within the set criterion.

The reference scenario inherits the characteristics of the current situations on the ground. It enables a better understanding of the current trend. The other scenarios are variations of this actual picture in a bid to achieve a set goal.

3.6.1 Ethical consideration

Since the study involved human respondents, the research developed approaches that ensured the success of the study. Ethical issues were critical at this point since they provided standards and norms of behaviour that outlined the moral relationship between the researcher and the responded (Copper and Shindler 2008). the researcher ensured that there was no potential risk connected to the study. The researcher took some approaches to ensure confidentiality of the collected data. First, personal information was not included in the questionnaire. Second, the collected data was not used for any reasons other than they specified study. Third, the collected data was kept relatively safe.

Chapter Four: RESULTS AND DISCUSSION

Common pool resources management especially amongst transboundary resources is a well-established discipline given that the goal being sought after is the cooperative management of the shared resource to maximize on the returns and sustainability (Agarwal, Rajiv, Yadav, & Haldar, 2005). Water allocation conflicts can be addressed in the same framework.

Two scenarios based on the reference scenario were analysed to project different Demand management strategies within the basin. These scenarios were;

Scenario	Description
Enhanced water policies	The scenario assessment of alternate water sources
Increased DMS	Utilization of measures such as; Tiered water pricing Water efficient appliances Increased monitoring

Table 9 Scenario description

4.1 Reference Scenario

The base line scenario (Reference Scenario) is one in which the current actual situation is modelled and projected under current situations/conditions. The current account year is set as 2010. The base line is extended to the year 2045. The model mimics the actual happenings.

The assumptions include;

1. Linear population growth rate based recent KNBS *Fig*ures (2010,2014).
2. Urban and rural population lumped into one demand node (human water needs) at the various catchments.
3. Water is priced per cubic metre.
4. The water allocation priority was based on the following criteria;

Demand	Priority
Domestic	1
Livestock	2
Agriculture	3
Other uses	4
Dams and Reservoirs	5

Table 10 Priority table

This scenario adopted the business as usual scenario, mimicking current activities on going in the basin and adopted the following assumptions;

parameter	Value
Human population growth rate	3.0%
Per capita water consumption (Human)	150l/day
Price per cubic metre	

Table 11 assumptions in the model

Water demand projections

Under the reference scenario, the water demand projections at all nodes show a remarkable increase in the abstraction levels in all the catchments/abstraction points. The major demand nodes for the water utilized from the analysis were human consumption and irrigation (both large scale and small scale irrigation). The MRB is poised to experience a gradual increase in demand as illustrated in the *Fig*ures below. For example, within the Amala catchment, the total demand on the Mara river is projected to rise from 0.03BCM in the year 2013 to 1.40 BCM in the year 2045.

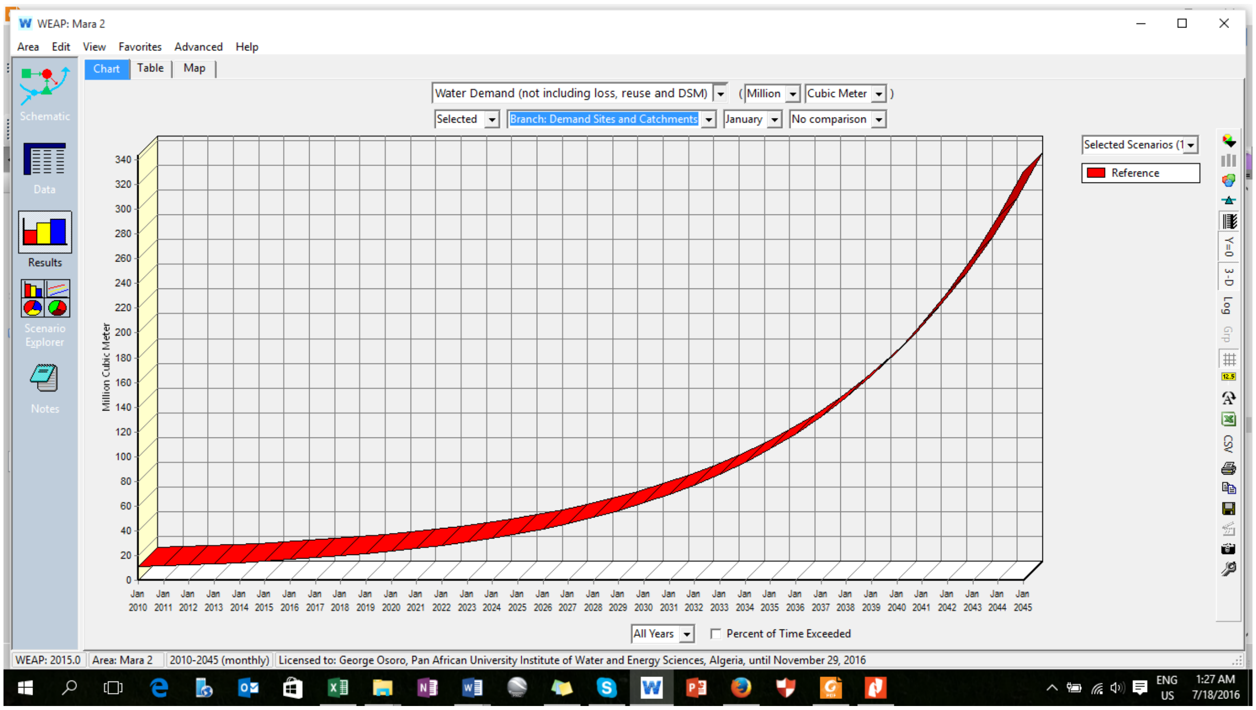

Figure 4:1 Annual water demand projection

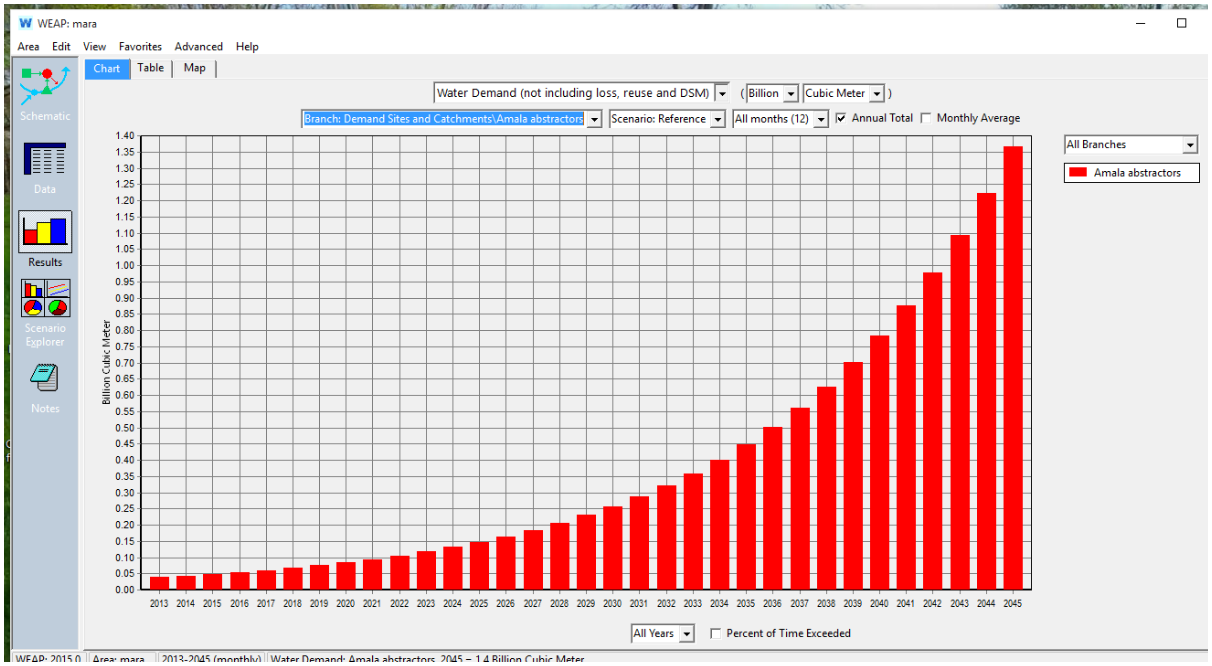

Figure4:2 Amala water Demand Projection

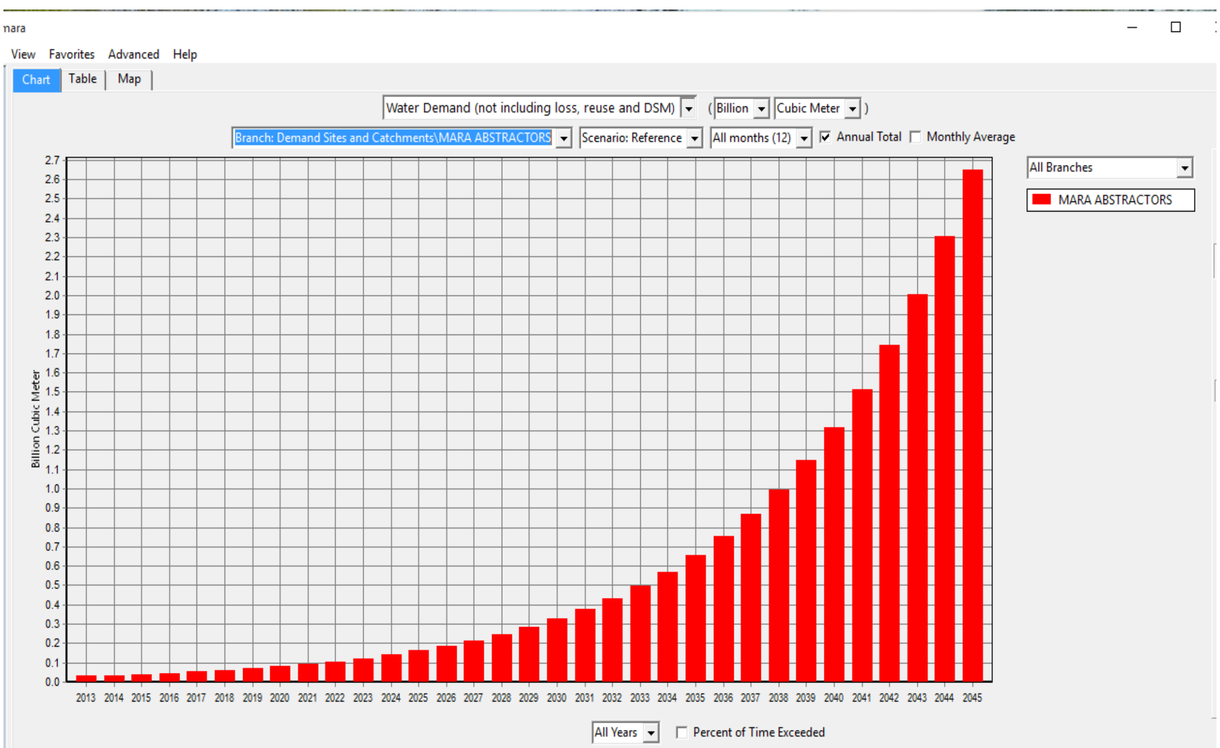

Figure4:3Mara river Water Demand Projection

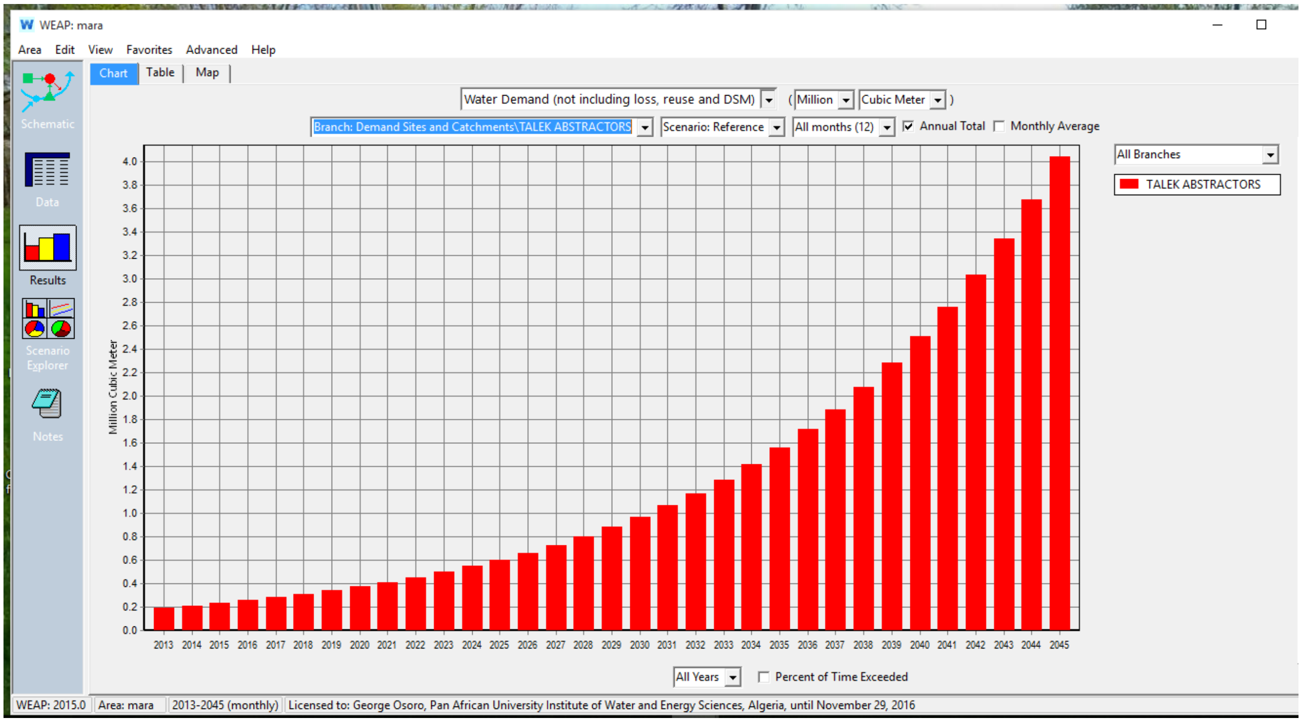

Figure4:4 Talek Demand Projections

Human demand

The human demand was estimated by combining both the local and urban population. The data was based on the latest census *Fig*ures obtained from the national statistical organization websites the Kenya National bureau of statistics and the Tanzania national bureau of statistics (www.knbs.go.ke , www.nbs.tz , www.opendata.go.ke and www.citypopulation.de).

District/County	Population	Water quantity needed per day(m3)
Bomet	891,385*	133,707.75
Narok	365,750*	54862.5
Trans mara	274,532*	41,179.8
Tarime	339,693**	50,953.95
Serengeti	240,420**	36,063
Musoma rural	178,356**	26,753.4

Table 12 Population within the MRB

*Source www.opendata.go.ke www.knbs.go.ke based on 2009 census data ** source http://www.citypopulation.de http://www.nbs.go.tz/ based on 2012 census *Fig*ures

UNMET DEMANDS AND DEMAND SITE COVERAGE

A linear allocation algorithm is applied to satisfy demand in WEAP. In this situation, demand site satisfaction is bound to classification attributes such as demand priority, supply preference and mass balance being satisfied.

This is achieved through the implementation of a linear allocation model/policy being utilized in the MRB. However economically based needs such as tourism and large scale agriculture water needs are not met throughout the year. The unmet demands start in June for tourism and end in March. The unmet demands for large scale irrigation varies throughout the year.

On average the demand site coverage is above 80%. This can be attributed to the adequate water budget within the MRB ensuring that sufficient water is available to meet its annual basin wide demand (Dessu & Melesse, 2012).

In the results illustrated in *Fig*. 4.5, The water requirements for select demands within the MRB such as Human, livestock and wildlife needs are met within the reference scenario.

The months of April and May show the least amount in terms of unmet coverage at 12.3 and 15.2 MCM while the largest unmet demand are experienced during the months of February, July and December at 40.2 ,42.9 and 43.1 MCM.

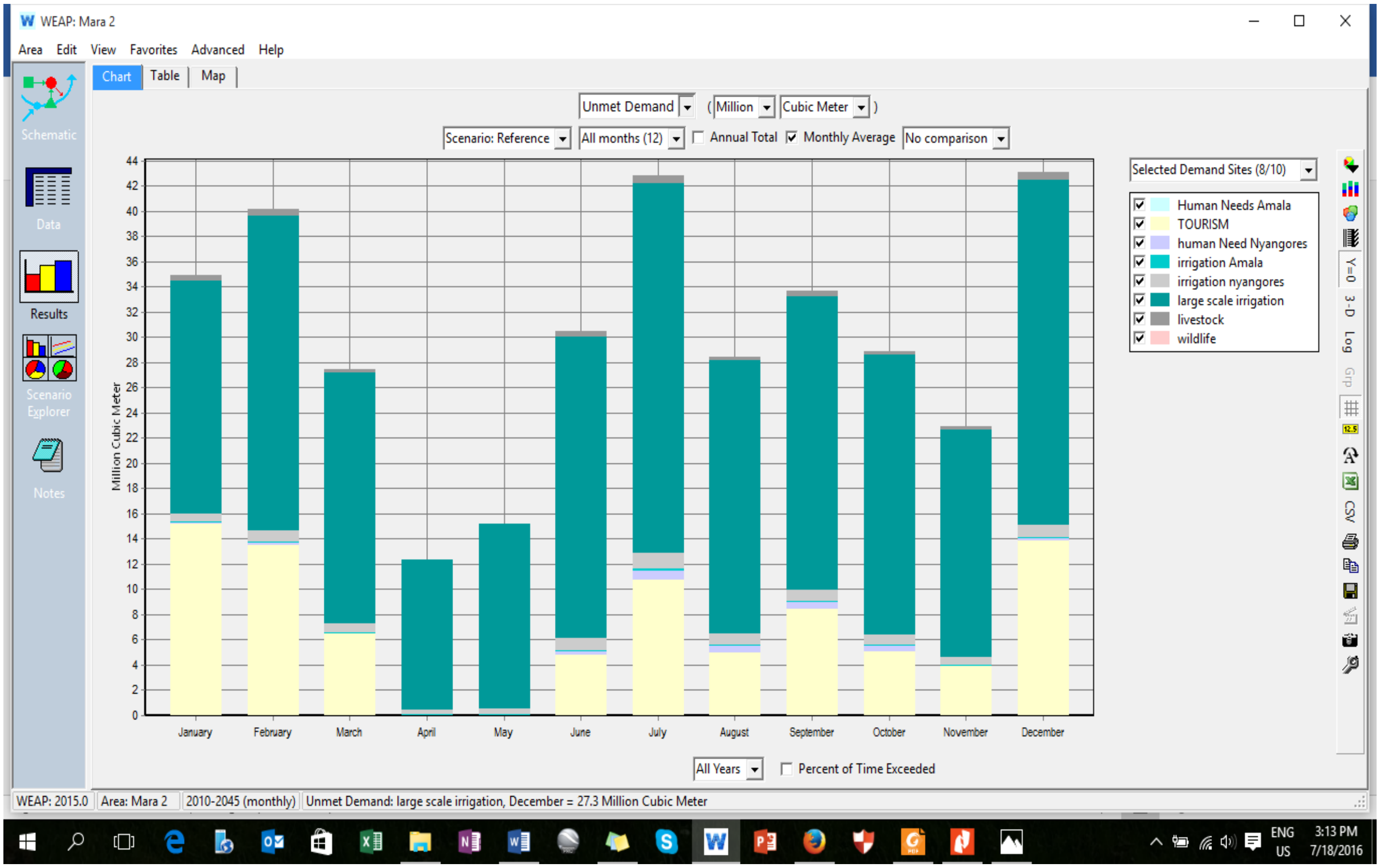

Figure4:5 Unmet demands monthly

Fig 4.6 illustrates that the water demands within the MRB are sufficiently met for all demand sites until the year 2028 but significant effects are visible from the year 2033.

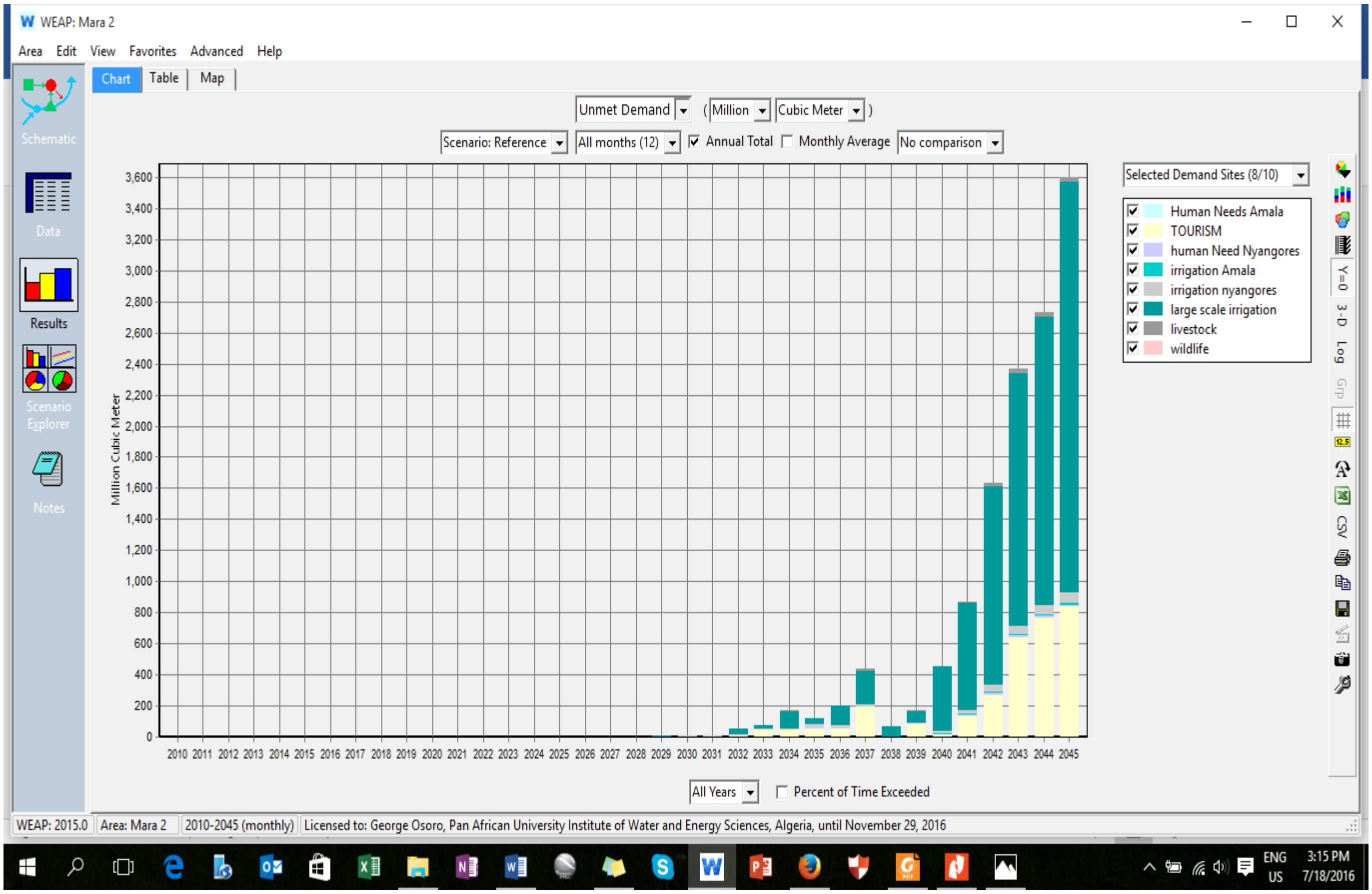

Figure 4:6 Annual unmet demands

Fig 4.5 and *Fig* 4.6, illustrates that all demand site needs are sufficiently met until the year 2028 (*Fig* 4.6.), when external factors such as increased population pressure and climatic variability (Hoffman, 2007; Dessu, Melesse, & Bhat, 2013). Other factors such as land use change (Mati, et al., 2008) may also be factors that contribute to the sudden change.

Economic factors such as agricultural based initiatives such as large scale irrigation farming seem to be the most intensive water demand areas followed by tourism. The total unmet demand for irrigation agriculture grows from 35.1 MCM in the year 2032 to 2641.0 MCM in the year 2045.

On the other hand, the unmet demand for tourism increased from 6.3 MCM in 2032 to 837.9 MCM in 2045.

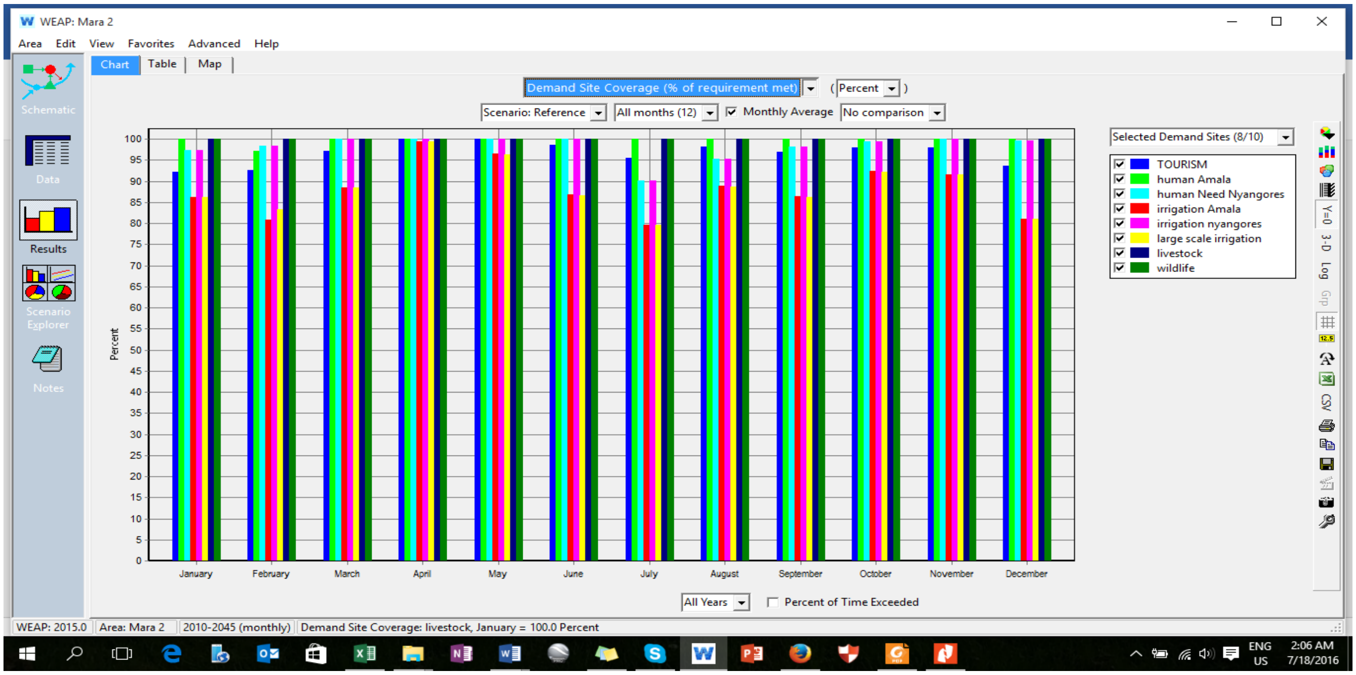

Figure 4:7 Demand site coverage

4.2 Scenario One: Enhanced Policies Implementation

Kenya and Tanzania have made strides into ensuring that there is portable water available to its residents within the basin but there are still some constrains. Previous studies (Dessu, Melesse, & Bhat, 2013); KNBS 2007) show that on the Kenyan side a large number of the population, more than 50%, obtain their water directly from Mara river, piped water penetration is estimated at 14% ,25% from springs and wells.

This scenario modelled the impact of recent governmental policies such as the Integrated Water Resources Management and Efficiency Plan (2009) and the water acts of 2014(Kenya) and 2008(Tanzania) have provided robust growth mechanisms for water management. Tools such as the catchment management strategies (CMS) are such policy tools brought on board.

In this scenario, flow requirements were introduced, CMS objectives based on sub catchment management plans for the various sub catchments were introduced into the model.

Fig 4.2.1 illustrates the demand site coverage under this scenario is at an average of 95%. All water needs are met with slight fluctuations in the months of February and July at the irrigation nodes as they are water intensive activities.

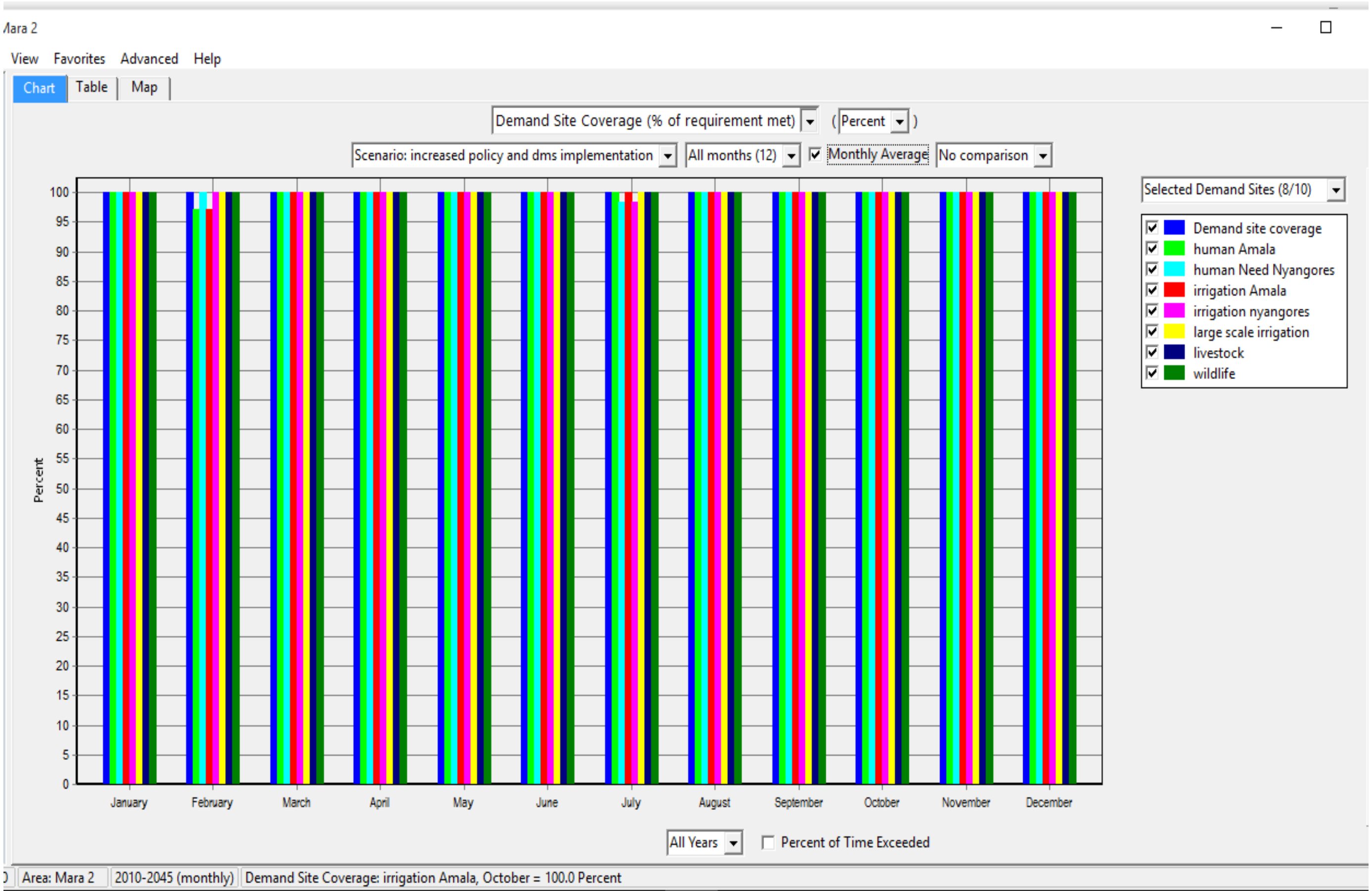

Figure 4.2:8 Demand site coverage in the Enhanced policy and DMS scenario

Water demands

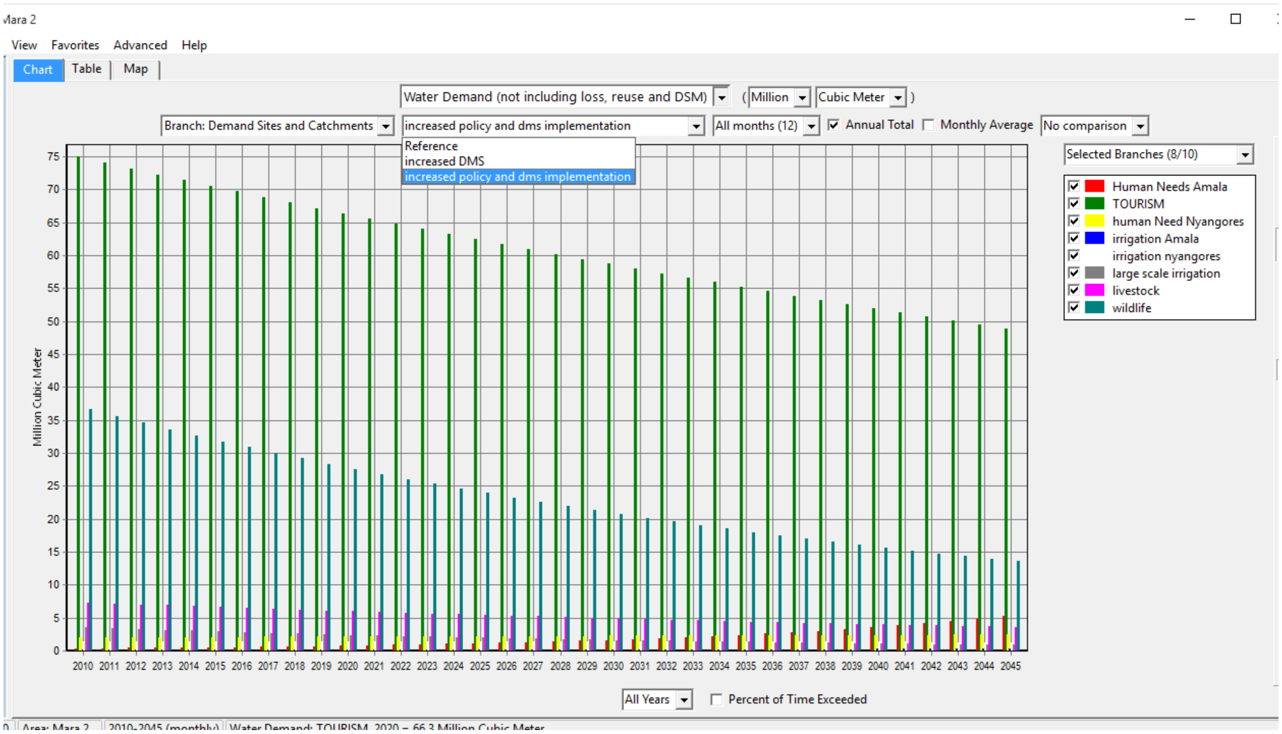

Figure 4.2:9 water demand coverage in Scenario 1

Water demands simulation in the Enhanced policy implementation Scenario shows a gradual decline in water demand within the MRB. In the year 2010, the demand is projected as 126.2 MCM across all demand nodes. This demand shows a reducing trend falling by an average of 2% annually. On the other hand, the reference scenario shows an increasing trend in the total demand within the MRB. This is illustrated in figure 4.2.2, which shows the increase in demand from 126.2 MCM in 2010 to 5,922 MCM in 2045. The average increasing rate is 8% in the reference scenario.

However, there is a gradual increase in the water demand attributed to human needs around the Amala catchment. This can be due to an influx of new settlers within the surrounding urban centres hence the increase.

Unmet demands

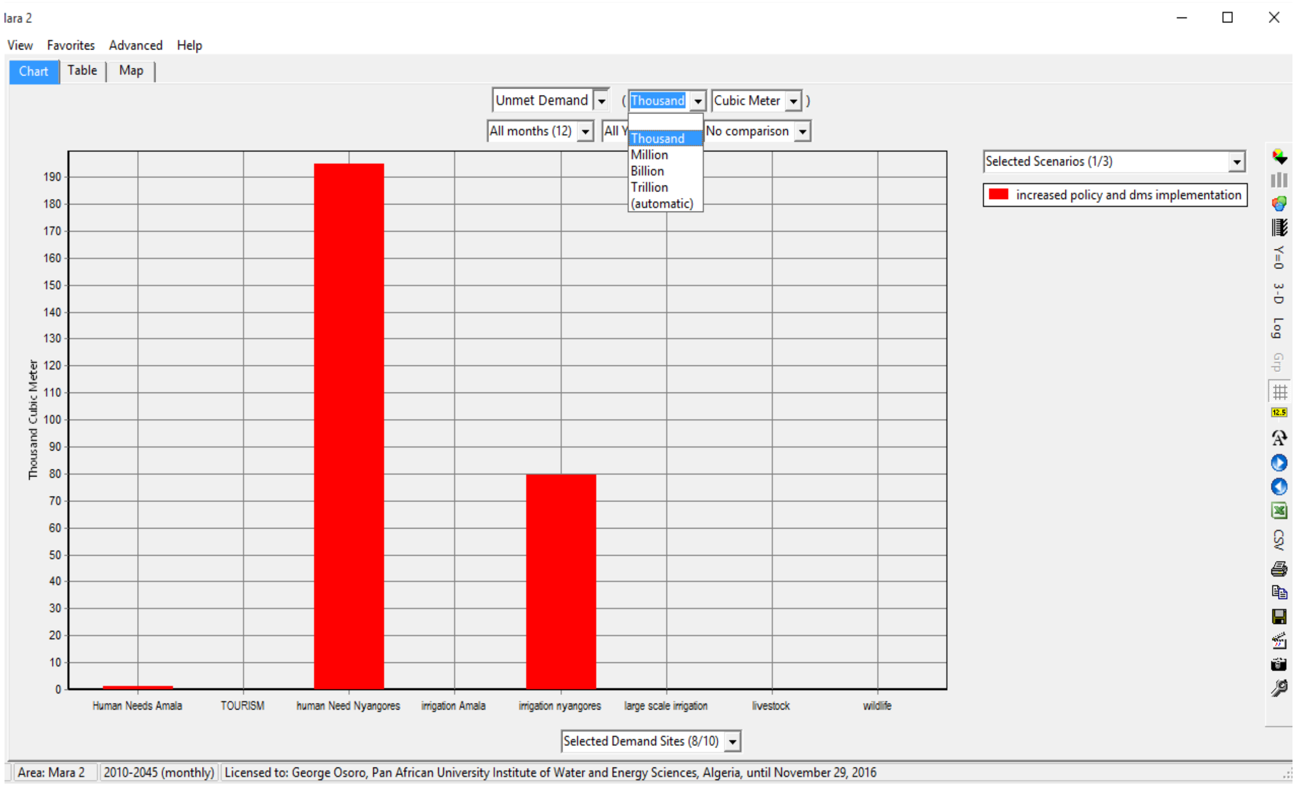

Figure 4.2:10 Unmet demand water nodes

Anticipated factors such as population increase and increased land use change from forested lands to agricultural use especially at the upper parts of the MRB especially around the Mau forest zone (Nyangores and Amala catchments), have resulted to more strain on the scarce resource.

The MRB does not satisfy the demand requirements at the human needs node situated at Nyangores and Amala while the irrigation needs at the Nyangores sub catchment was not met. The unmet demands ranged from **196,081 cubic metres**, while the irrigation deficit is pegged at **79.7 thousand cubic metres**. An analysis of the annual unmet demand shows that the demand is unmet during the years 2010 and 2022. the water demands are fully met during the rest of the years. This is in line with recent findings that peg a drought occurrence within the basin to a cycle of seven years.

During the year 2010,(*fig 4.2.4*.) the total unmet demand is estimated to be 274,328 cubic metres while in 2022 the unmet demand is estimated to be 1,443 cubic metres. Analysis of the difference between the two unmet water values illustrated that the MRB policy interventions such as alternative water sources, recycling initiatives and awareness creation are viable options to tackle water scarcity within the MRB.

The tourism, large scale agriculture, wildlife and livestock water needs were sufficiently met in this scenario.

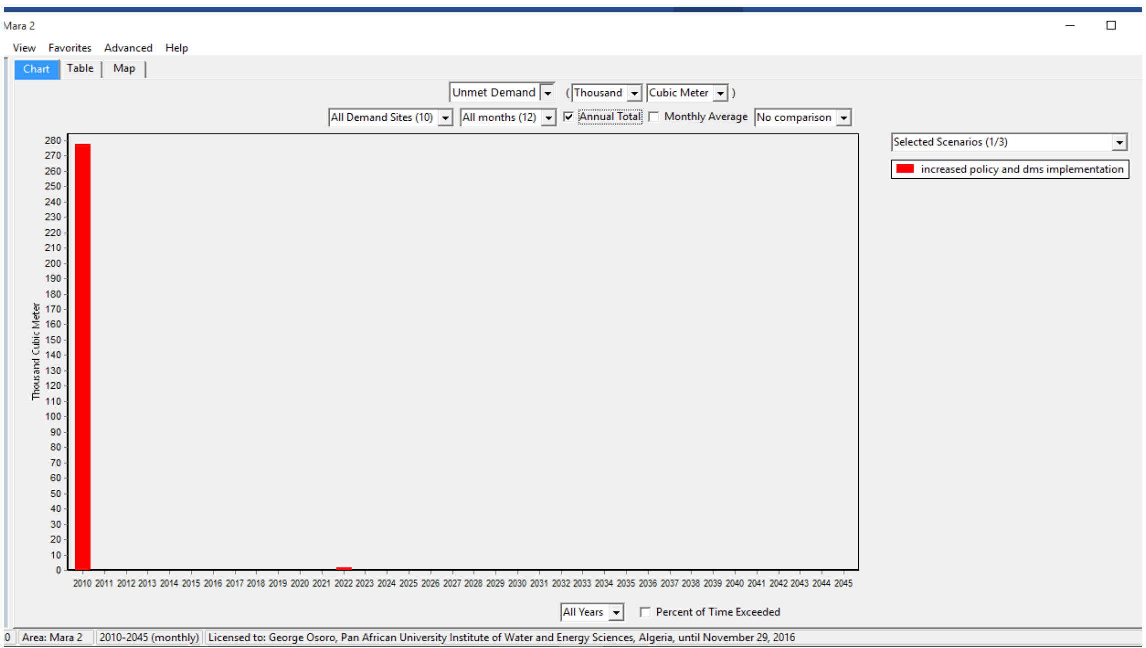

Figure4.2:11 Annual unmet water demand

The reduction in unmet demands within the Enhanced Policy and DMS scenario shows a great reduction in the volume of unmet water demands within the MRB compared with the baseline case. A case in point is that during the later part of the simulated period (2035- 2045), there is no net defict in unmet demands as illustrated in the reference scenario.

This scenario indicates that water stress in the MRB can be alleviated. This is achieved through the utilisation of policy tools like catchment management strategies,the respective water laws and acts,water recyling within the farms and tourism hotels and lodges. For example the savings achieved through these initiatives have resulted in the divertion of 2641 MCM cubic metres pooled from other sectors to fully satisfy the unmet large scale irrigation needs in the year 2045.

It can also be argued that the key awareness initiatives and environmental policing by individual water resource users associations within their respective areas also had an overall positive impact.

4.3 Scenario Two: Increased DMS Implementation

This scenario simulated the impact of **Increased Demand Management Strategies** on the reference scenario.

Previous studies (Gereta, Wolanski, Borner, & Serneels, 2002; Dessu, Melesse, & Bhat, 2013) have postulated that the ensuing scarcity of water within the MRB requires equitable management and trade-offs between demand sectors.

In this scenario two items were simulated;

1. The effect of water pricing in the MRB
2. More efficient and water saving techniques such as improved irrigation efficiency and water reuse rates of above 60%

Key assumptions in this scenario

1. Constant and linear population growth rate at 3.0 % in the basin
2. Increased penetration of water availability within the MRB
3. 45% of the population have alternative water supply sources such as harvested rain water and springs and wells.
4. Water pricing is based on a block tiered format.

Demand site coverage

The coverage of all demand sites within this scenario was at an average 96% throughout the years. In terms of monthly coverage, all demand sites are sufficiently covered at 100% apart from the Month of February where there is a slight deviation where the coverage is at 96% (figure 4.3.1).

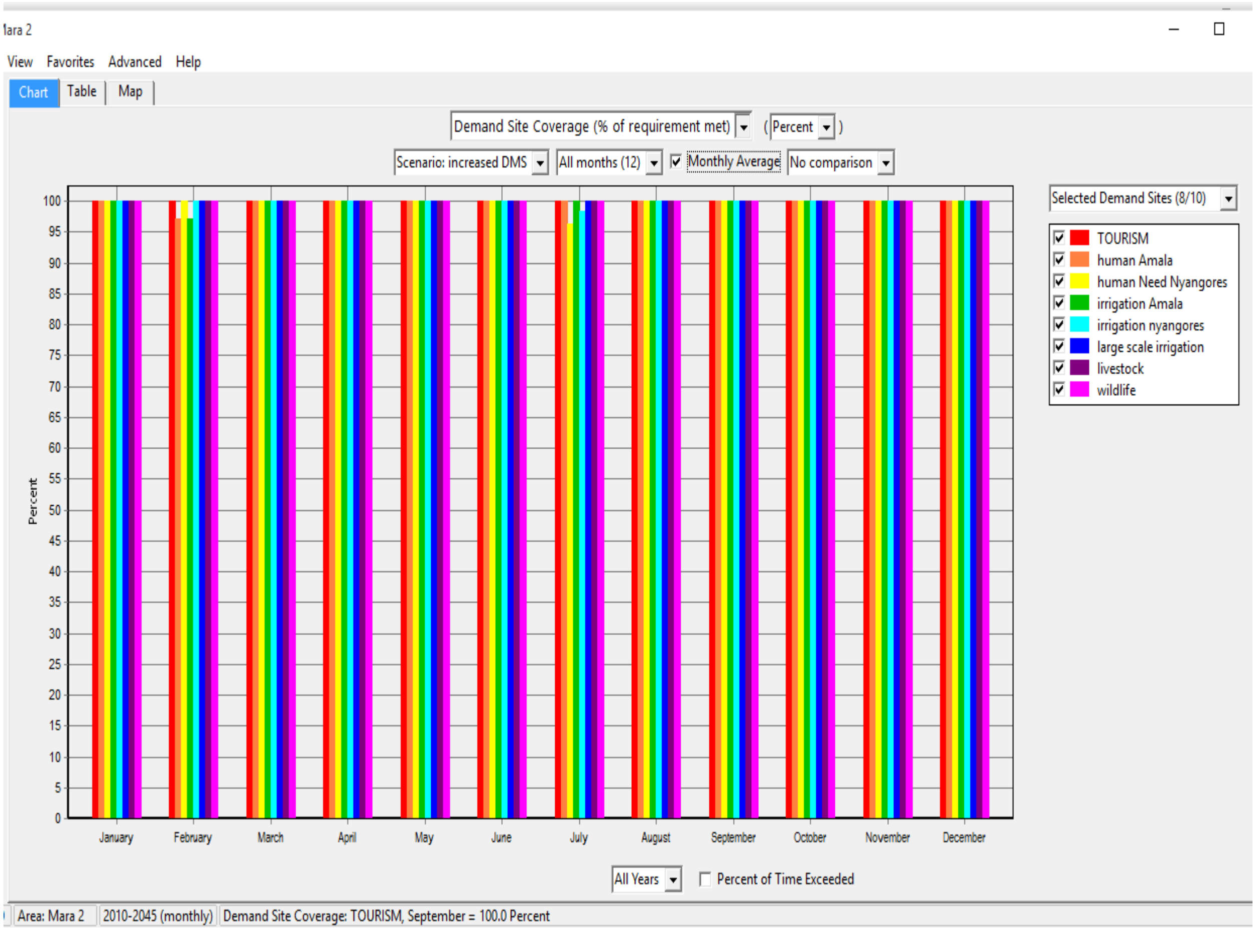

Figure 4.3:12 demand site coverage increased DMS scenario

Water demand and unmet demand

In the reference scenario, the water demand in the year 2010, is about 126.2 MCM and it shows an increasing trend as it rises in value to 5,922 MCM in the year 2045. The increase within the period is an increase of 98% from the initial demand experienced during the base year. Conversely, under the increased DMS scenario, the initial demand in the year 2010 is 126.2 MCM, and dwindles down to 105.0 MCM during the year 2045(figure 4.3.2).

The water demand shows a drastic decrease compared to the baseline case scenario. On a monthly average, the month of February experienced a demand shortfall of 254 cubic metres at the demand nodes within the Amala Catchment (Human needs – 191.8 and 62.1 cubic metres) and in the month of July when a total of 9995 cubic metres shortfall being experienced within the Nyangores catchment demand points (Irrigation 2209.4 and human needs 7785.6 cubic metres respectively).

On the other hand, the annual unmet demand analysis between the reference scenario and the increased DSM scenario illustrates a net reduction of total unmet demand during the simulation periods. This is illustrated by the figures given out by the model where in the reference scenario the total unmet demand within the simulated period was 12,976.2 MCM while in the DSM scenario the is 369 thousand cubic metres.

This can be explained with respect to the improved water saving technologies implemented as a water saving technique. Some of these techniques include;

1. The utilization of water efficient taps within the homes, luxury camps and lodges,
2. Enhanced water transmission networks (a key factor input for urban centres within the MRB)
3. Water reuse especially grey water reuse within institutions and facilities.

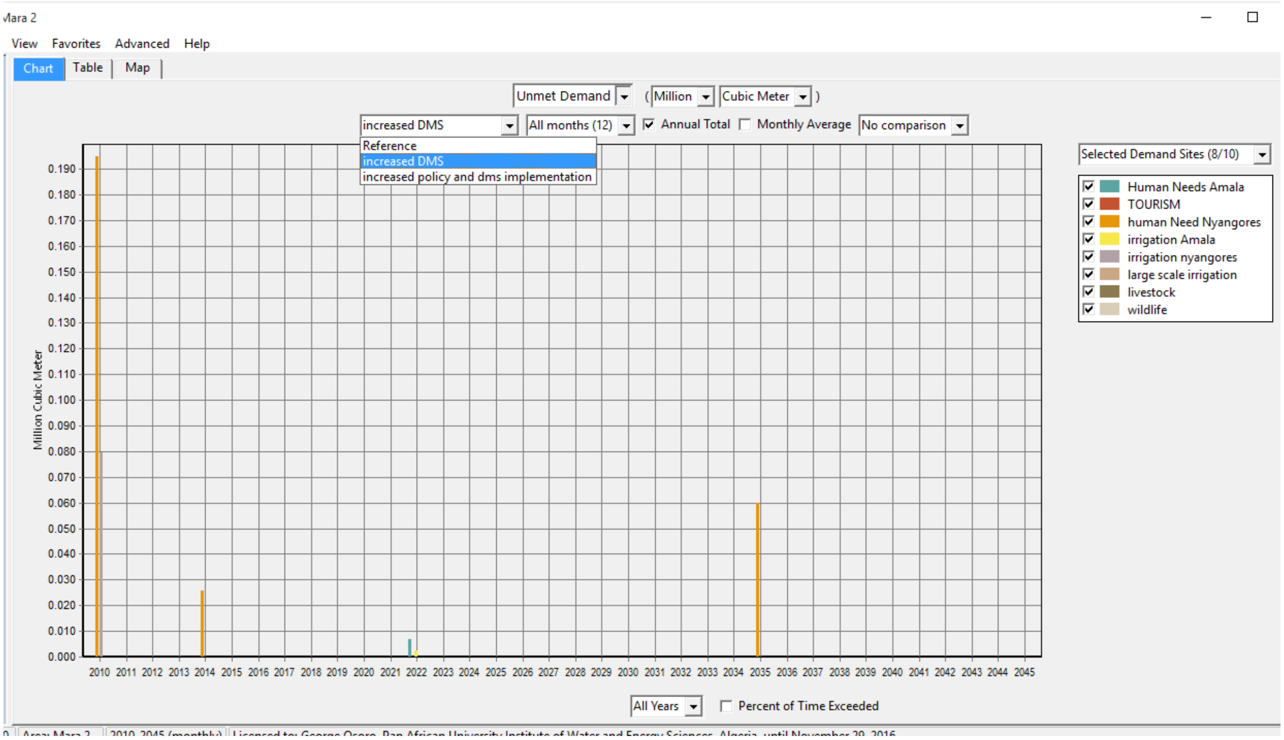

Figure 4.3.2 Unmet annual demand

Enhanced water transmission networks

Improved Irrigation efficiency this is achieved through feature /facility improvement such as, proper maintenance of intake structures such as canals, lining of the structures to reduce seepage, and utilization of more water efficient irrigation techniques such as drip irrigation instead of sprinkler irrigation.

The effect of improved irrigation efficiencies is evident from the reduced water consumption from 3.8 MCM in the year 2010 to 2.9 MCM in the year 2045. This compared to the same water use in the reference scenario where in the year 2045 about 16.7 BCM are utilized.

In the reference scenario, in the year 2010, 4.9 MCM is utilized in irrigation. On the other hand, within the DMS scenario, 3.8 MCM is utilized. This shows a reduction of 1.1 MCM of water saved through the enhanced irrigation techniques. This shows a saving of about 78% of water resources previously committed to irrigation activities.

Water pricing

In the reference scenario, the water pricing is based on the current water use rates and charges where all water abstractors pay a flat fee of 0.50 KES per cubic metres upon abstraction.

The Dublin principles recognize that water is an economic good. Recent sectoral activities and publications are upping the ante on this in a bid to strike a balance between the provision of adequately safe and reliable potable water and also conservation of the resource in terms of its protection, rehabilitation and sustainable utilization within acceptable limits.

Recent studies by Kadigi et al (2004); Mwakalila (2006); Wheeler et al. (2008) illustrated that water demands are price elastic. These studies focused mostly on commercial irrigated agriculture and related returns.

On the other hand, studies by done recently within the MRB (Dessu, Melesse, & Bhat, 2013) illustrated that the water demands within the basin are price inelastic with a catch that studies have not been done to establish a consumption pattern with price fluctuations.

Studies carried out by Hashimoto (2008) and Dienya and Gicheru (2012) on household water consumption and demand illustrated that areas of abundant water supply such as Mulot, the residents paid an average of 5.00 KES per 20 litres of water while in areas such as the sections lower in the MRB in less water abundant water zone the people were willing to pay upwards of 9.71KES.

Taking this change as a representative sample of price variation with scarcity, a water pricing strategy modelled on increased water demand was adopted.

Block and Tiered Model

Water pricing touches on all the economic activities that take place within the MRB. Factors such as the price elasticity of demand, water use rates were taken into account when simulating sectors such as industry, agriculture(irrigation) and human consumption. This is because the price charged will affect the amount of raw water abstracted. On the other hand, the higher the price charged to sectors such as irrigation, the Industry will enhance water saving measures such as water reuse and rain water harvesting.

The water Resources management authority charges about 0.50 KES per cubic meters. However, the water service providers charge a little higher and uses the block tier format.

Modelling water pricing within the scenario utilized the block tier format. The initial 10 cubic metres for irrigation and tourism/industrial demands were billed at a flat rate of 10KES per metre. For every additional 2 cubic metres the price increases by 25 KES.

Water reuse

Water reuse rate for the demand nodes was modelled as follows;

Demand site	Reuse percentage
Tourism	50%
Irrigation	65%
Domestic	60%
Industrial	60%

Table 13 table showing water reuse rates as utilized in the model

The tourism demand, modelled with the reuse option showed a reduction as evidenced by the difference between the reference scenario and the increased DMS scenario. This is illustrated in table below:

Year	Reference (MCM)	Increased DMS(MCM)
2010	75	75
2015	125.6	74.9
2020	210.6	74.9
2025	352.9	74.9
2030	591.4	74.8
2035	991.3	74.8
2040	1,661.3	74.8
2045	2,784.3	74.8

Table 14 Comparison between Reference and Increased DMS on Tourism water demand

Based on this analysis, the raft of interventions in the increased DMS strategy show a promise of a net positive impact on water resources in the MRB

Chapter Five: CONCLUSION

The MRB is projected to experience strain and pressure increases on its resources; water and land. This is attributed to the positive robust growth in settlements within the basin and conversion of more previously forest and range lands into farms.

Climate variability studies using scaled down GCM predict wetter rainy seasons and drier dry seasons (Dessu & Melesse, 2012). This is reinforced by studies done on the discharge where it is postulated that the variability will result in higher peak flows in the wet period and lower flows in the drier months (Mati, et al., 2008).

From the above scenario results, the effects of properly enhanced policy implantations and awareness creation coupled with the demand management strategies will ensure that adequate water is available in the bas in at all times. However, water abstraction ceilings should be put on the water abstractors during the dry seasons to ensure that the gazette flow rates allocated to reserve flows are maintained for the sustainability of the river.

The lack of water storage facilities within the basin such be addressed as a matter of urgency. A reservoir in the upper portion will enhance water security, while Sand dams especially in the lower portions of the river will help in tackling the water pollution being experienced in the area.

It is evident from the study, that the current problems facing the MRB can only be mitigated through an integrated approach. The approach can harness the effects of increased population growth, climate variability and enhanced economic activities vis-a-vis irrigation in a concerted manner.

The utilisation of specific demand management strategies such as rain water harvesting at the local household level, the utilisation of technology in grey water reuse within the commercial facilities and use of artificial wetlands will go a long way in the mitigation of the increasing water demand within the MRB. Policy interventions targeting these strategies in a bid to make it easier to implement them will be a commendable boost.

In this regard, a holistic IWRM strategy will work best.

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Appendix

	SIM	OBS	LOG SIM	LOG OBS	ERROR	ABS ERR	SQR ERR	LOG ERROR
Jan-10	36.149	36.149	1.558096	1.558096	0	0	0	0
Feb-10	43.34	43.34	1.636889	1.636889	0	0	0	0
Mar-10	47.086	47.086	1.672892	1.672892	0	0	0	0
Apr-10	14.357	14.357	1.157064	1.157064	0	0	0	0
May-10	19.841	19.841	1.297564	1.297564	0	0	0	0
Jun-10	0.60014	0.60014	-0.22175	-0.22175	0	0	0	0
Jul-10	0.029284	0.029284	-1.53337	-1.53337	0	0	0	0
Aug-10	0.18172	0.18172	-0.7406	-0.7406	0	0	0	0
Sep-10	0.99875	0.99875	-0.00054	-0.00054	0	0	0	0
Oct-10	28.439	28.439	1.453914	1.453914	0	0	0	0
Nov-10	10.781	10.781	1.032659	1.032659	0	0	0	0
Dec-10	44.421	44.421	1.647588	1.647588	0	0	0	0
Jan-11	10.431	11.884	1.018326	1.074963	-1.453	1.453	2.111209	0.056637
Feb-11	11.568	13.022	1.063258	1.114678	-1.454	1.454	2.114116	0.051419
Mar-11	40.813	42.266	1.610799	1.625991	-1.453	1.453	2.111209	0.015193
Apr-11	85.679	87.133	1.932874	1.940183	-1.454	1.454	2.114116	0.007308
May-11	13.228	14.681	1.121494	1.166756	-1.453	1.453	2.111209	0.045261
Jun-11	0.48303	1.9363	-0.31603	0.286973	-1.45327	1.45327	2.111994	0.602999
Jul-11	0.49984	1.9531	-0.30117	0.290724	-1.45326	1.45326	2.111965	0.591893
Aug-11	12.438	13.892	1.094751	1.142765	-1.454	1.454	2.114116	0.048014
Sep-11	0.47277	1.926	-0.32535	0.284656	-1.45323	1.45323	2.111877	0.610006
Oct-11	12.94	14.393	1.111934	1.158151	-1.453	1.453	2.111209	0.046217
Nov-11	6.6755	8.1288	0.824484	0.910026	-1.4533	1.4533	2.112081	0.085543
Dec-11	5.6092	7.0625	0.748901	0.848958	-1.4533	1.4533	2.112081	0.100058
Jan-12	24.673	26.126	1.392222	1.417073	-1.453	1.453	2.111209	0.024851
Feb-12	18.5	19.952	1.267172	1.299986	-1.452	1.452	2.108304	0.032815
Mar-12	4.3529	5.8052	0.638779	0.763817	-1.4523	1.4523	2.109175	0.125038
Apr-12	30.234	31.687	1.480496	1.500881	-1.453	1.453	2.111209	0.020386
May-12	4.1464	5.5988	0.617671	0.748095	-1.4524	1.4524	2.109466	0.130424
Jun-12	34.815	36.267	1.541766	1.559512	-1.452	1.452	2.108304	0.017745
Jul-12	0.17443	1.6268	-0.75838	0.211334	-1.45237	1.45237	2.109379	0.969713
Aug-12	12.411	13.863	1.093807	1.141857	-1.452	1.452	2.108304	0.04805
Sep-12	0.76309	2.2154	-0.11742	0.345452	-1.45231	1.45231	2.109204	0.462876
Oct-12	11.658	13.111	1.066624	1.117636	-1.453	1.453	2.111209	0.051012
Nov-12	1.3548	2.8072	0.131875	0.448273	-1.4524	1.4524	2.109466	0.316398
Dec-12	1.0301	2.4824	0.012879	0.394872	-1.4523	1.4523	2.109175	0.381992
Jan-13	0.5444	1.9979	-0.26408	0.300574	-1.4535	1.4535	2.112662	0.564656
Feb-13	13.649	15.102	1.135101	1.179034	-1.453	1.453	2.111209	0.043934
Mar-13	1.583	3.0365	0.199481	0.482373	-1.4535	1.4535	2.112662	0.282892
	SIM	OBS	LOG SIM	LOG OBS	ERROR	ABS ERR	SQR ERR	LOG ERROR

Apr-13	2.748	4.2015	0.439017	0.623404	-1.4535	1.4535	2.112662	0.184388
May-13	15.054	16.508	1.177652	1.217694	-1.454	1.454	2.114116	0.040043
Jun-13	3.5398	4.9933	0.548979	0.698388	-1.4535	1.4535	2.112662	0.149409
Jul-13	3.4867	4.9402	0.542415	0.693745	-1.4535	1.4535	2.112662	0.15133
Aug-13	0.13617	1.5897	-0.86592	0.201315	-1.45353	1.45353	2.112749	1.067234
Sep-13	0.95695	2.4104	-0.01911	0.382089	-1.45345	1.45345	2.112517	0.4012
Oct-13	10.454	11.908	1.019282	1.075839	-1.454	1.454	2.114116	0.056556
Nov-13	8.617	10.07	0.935356	1.003029	-1.453	1.453	2.111209	0.067673
Dec-13	17.524	18.977	1.243633	1.278228	-1.453	1.453	2.111209	0.034594
Jan-14	36.17	37.624	1.558349	1.575465	-1.454	1.454	2.114116	0.017116
Feb-14	51.639	53.094	1.712978	1.725045	-1.455	1.455	2.117025	0.012068
Mar-14	3.8102	5.2648	0.580948	0.721382	-1.4546	1.4546	2.115861	0.140434
Apr-14	0.40013	1.8547	-0.3978	0.268274	-1.45457	1.45457	2.115774	0.666073
May-14	1.0441	2.4987	0.018742	0.397714	-1.4546	1.4546	2.115861	0.378972
Jun-14	1.0753	2.5299	0.03153	0.403103	-1.4546	1.4546	2.115861	0.371574
Jul-14	0.013819	1.439	-1.85952	0.158061	-1.42518	1.425181	2.031141	2.017584
Aug-14	0.19262	1.6472	-0.7153	0.216746	-1.45458	1.45458	2.115803	0.932045
Sep-14	0.22318	1.6778	-0.65134	0.22474	-1.45462	1.45462	2.115919	0.876085
Oct-14	0.20568	1.6603	-0.68681	0.220187	-1.45462	1.45462	2.115919	0.906995
Nov-14	0.3641	1.8187	-0.43878	0.259761	-1.4546	1.4546	2.115861	0.69854
Dec-14	0.22774	1.6824	-0.64256	0.225929	-1.45466	1.45466	2.116036	0.86849
Jan-15	0.048607	1.4921	-1.3133	0.173798	-1.44349	1.443493	2.083672	1.487099
Feb-15	26.175	27.63	1.417887	1.441381	-1.455	1.455	2.117025	0.023494
Mar-15	60.539	61.995	1.782035	1.792357	-1.456	1.456	2.119936	0.010321
Apr-15	44.597	46.053	1.649306	1.663258	-1.456	1.456	2.119936	0.013952
May-15	6.6354	8.0911	0.821867	0.908008	-1.4557	1.4557	2.119062	0.08614
Jun-15	16.581	18.036	1.219611	1.25614	-1.455	1.455	2.117025	0.03653
Jul-15	0.36401	1.8198	-0.43889	0.260024	-1.45579	1.45579	2.119325	0.69891
Aug-15	0.68103	2.1368	-0.16683	0.329764	-1.45577	1.45577	2.119266	0.496598
Sep-15	0.63508	2.0909	-0.19717	0.320333	-1.45582	1.45582	2.119412	0.517505
Oct-15	0.67789	2.1337	-0.16884	0.329133	-1.45581	1.45581	2.119383	0.497974
Nov-15	68.324	69.78	1.834573	1.843731	-1.456	1.456	2.119936	0.009158
Dec-15	4.819	6.2748	0.682957	0.7976	-1.4558	1.4558	2.119354	0.114643
Jan-16	12.54	13.997	1.098298	1.146035	-1.457	1.457	2.122849	0.047737
Feb-16	7.3886	8.8455	0.868562	0.946722	-1.4569	1.4569	2.122558	0.07816
	SIM	OBS	LOG SIM	LOG OBS	ERROR	ABS ERR	SQR ERR	LOG ERROR
Mar-16	48.097	49.554	1.682118	1.695079	-1.457	1.457	2.122849	0.012961
Apr-16	50.807	52.264	1.705924	1.718203	-1.457	1.457	2.122849	0.012279
May-16	21.557	23.014	1.333588	1.361992	-1.457	1.457	2.122849	0.028404
Jun-16	1.3193	2.7762	0.120344	0.443451	-1.4569	1.4569	2.122558	0.323107
Jul-16	0.55903	2.0159	-0.25256	0.304469	-1.45687	1.45687	2.12247	0.557034
Aug-16	0.56543	2.0224	-0.24762	0.305867	-1.45697	1.45697	2.122762	0.553488
Sep-16	1.0214	2.4783	0.009196	0.394154	-1.4569	1.4569	2.122558	0.384958
Oct-16	2.2301	3.687	0.348324	0.566673	-1.4569	1.4569	2.122558	0.218349

Nov-16	10.233	11.69	1.010003	1.067815	-1.457	1.457	2.122849	0.057812
Dec-16	22.419	23.876	1.350616	1.377962	-1.457	1.457	2.122849	0.027345
Jan-17	38.778	40.236	1.588585	1.604615	-1.458	1.458	2.125764	0.016029
Feb-17	54.643	56.102	1.737535	1.748978	-1.459	1.459	2.128681	0.011444
Mar-17	29.2	30.658	1.465383	1.486544	-1.458	1.458	2.125764	0.021161
Apr-17	34.601	36.059	1.539089	1.557014	-1.458	1.458	2.125764	0.017925
May-17	17.034	18.492	1.231317	1.266984	-1.458	1.458	2.125764	0.035667
Jun-17	18.009	19.467	1.25549	1.289299	-1.458	1.458	2.125764	0.033809
Jul-17	20.468	21.926	1.311075	1.340959	-1.458	1.458	2.125764	0.029884
Aug-17	20.74	22.198	1.316809	1.346314	-1.458	1.458	2.125764	0.029505
Sep-17	12.108	13.566	1.083072	1.132452	-1.458	1.458	2.125764	0.049379
Oct-17	8.3569	9.8151	0.922045	0.991895	-1.4582	1.4582	2.126347	0.06985
Nov-17	18.765	20.223	1.273349	1.305846	-1.458	1.458	2.125764	0.032497
Dec-17	20	21.458	1.30103	1.331589	-1.458	1.458	2.125764	0.030559
Jan-18	21.632	23.091	1.335097	1.363443	-1.459	1.459	2.128681	0.028346
Feb-18	0.10891	1.5684	-0.96293	0.195457	-1.45949	1.45949	2.130111	1.158389
Mar-18	1.5412	3.0007	0.187859	0.477223	-1.4595	1.4595	2.13014	0.289364
Apr-18	4.6128	6.0723	0.663965	0.783353	-1.4595	1.4595	2.13014	0.119389
May-18	3.8144	5.2739	0.581426	0.722132	-1.4595	1.4595	2.13014	0.140706
Jun-18	3.9636	5.4231	0.59809	0.734248	-1.4595	1.4595	2.13014	0.136158
Jul-18	17.826	19.286	1.251054	1.285242	-1.46	1.46	2.1316	0.034188
Aug-18	23.966	25.425	1.379596	1.405261	-1.459	1.459	2.128681	0.025665
Sep-18	27	28.459	1.431364	1.45422	-1.459	1.459	2.128681	0.022856
Oct-18	29.59	31.049	1.471145	1.492048	-1.459	1.459	2.128681	0.020903
Nov-18	39.126	40.585	1.592465	1.608366	-1.459	1.459	2.128681	0.0159
Dec-18	38.593	40.053	1.586509	1.602635	-1.46	1.46	2.1316	0.016127
Jan-19	43.165	44.626	1.635132	1.649588	-1.461	1.461	2.134521	0.014456
Feb-19	41.373	42.834	1.616717	1.631789	-1.461	1.461	2.134521	0.015072
Mar-19	24.805	26.266	1.394539	1.419394	-1.461	1.461	2.134521	0.024855
Apr-19	28.616	30.077	1.456609	1.478235	-1.461	1.461	2.134521	0.021626
May-19	12.744	14.205	1.105306	1.152441	-1.461	1.461	2.134521	0.047135
Jun-19	15.129	16.59	1.17981	1.219846	-1.461	1.461	2.134521	0.040036
Jul-19	19.184	20.645	1.282939	1.314815	-1.461	1.461	2.134521	0.031876
Aug-19	20.958	22.419	1.32135	1.350616	-1.461	1.461	2.134521	0.029266
Sep-19	19.382	20.843	1.287399	1.31896	-1.461	1.461	2.134521	0.031562
	SIM	**OBS**	**LOG SIM**	**LOG OBS**	**ERRO R**	**ABS ERR**	**SQR ERR**	**LOG ERROR**
Oct-19	22.218	23.679	1.346705	1.374363	-1.461	1.461	2.134521	0.027658
Nov-19	31.508	32.969	1.498421	1.518106	-1.461	1.461	2.134521	0.019685
Dec-19	31.221	32.682	1.494447	1.514309	-1.461	1.461	2.134521	0.019862
Jan-20	35.793	37.256	1.553798	1.571196	-1.463	1.463	2.140369	0.017398
Feb-20	1.0802	2.5423	0.033504	0.405227	-1.4621	1.4621	2.137736	0.371723
Mar-20	43.83	45.292	1.641771	1.656021	-1.462	1.462	2.137444	0.01425
Apr-20	32.327	33.789	1.509565	1.528775	-1.462	1.462	2.137444	0.01921
May-20	2.5888	4.051	0.413098	0.607562	-1.4622	1.4622	2.138029	0.194464

Jun-20	0.69634	2.1585	-0.15718	0.334152	-1.46216	1.46216	2.137912	0.491331
Jul-20	0.43373	1.8959	-0.36278	0.277815	-1.46217	1.46217	2.137941	0.640596
Aug-20	24.864	26.326	1.395571	1.420385	-1.462	1.462	2.137444	0.024814
Sep-20	0.66528	2.1275	-0.177	0.32787	-1.46222	1.46222	2.138087	0.504865
Oct-20	0.53983	2.002	-0.26774	0.301464	-1.46217	1.46217	2.137941	0.569207
Nov-20	27.212	28.675	1.43476	1.457503	-1.463	1.463	2.140369	0.022743
Dec-20	24.647	26.109	1.391764	1.41679	-1.462	1.462	2.137444	0.025026
Jan-21	9.7346	11.198	0.988318	1.04914	-1.4634	1.4634	2.14154	0.060822
Feb-21	0.9233	2.387	-0.03466	0.377852	-1.4637	1.4637	2.142418	0.41251
Mar-21	2.9949	4.4586	0.476382	0.649199	-1.4637	1.4637	2.142418	0.172816
Apr-21	33.054	34.518	1.519224	1.538046	-1.464	1.464	2.143296	0.018822
May-21	1.5439	3.0076	0.188619	0.47822	-1.4637	1.4637	2.142418	0.289601
Jun-21	0.67397	2.1377	-0.17136	0.329947	-1.46373	1.46373	2.142506	0.501306
Jul-21	0.75673	2.2204	-0.12106	0.346431	-1.46367	1.46367	2.14233	0.46749
Aug-21	0.48127	1.945	-0.31761	0.28892	-1.46373	1.46373	2.142506	0.606531
Sep-21	0.46116	1.9249	-0.33615	0.284408	-1.46374	1.46374	2.142535	0.620557
Oct-21	0.91799	2.3817	-0.03716	0.376887	-1.46371	1.46371	2.142447	0.414049
Nov-21	63.074	64.538	1.79985	1.809816	-1.464	1.464	2.143296	0.009965
Dec-21	27.415	28.879	1.437988	1.460582	-1.464	1.464	2.143296	0.022594
Jan-22	85.786	87.251	1.933416	1.94077	-1.465	1.465	2.146225	0.007354
Feb-22	22.487	23.952	1.351932	1.379342	-1.465	1.465	2.146225	0.02741
Mar-22	3.7791	5.2443	0.577388	0.719688	-1.4652	1.4652	2.146811	0.142299
Apr-22	29.109	30.575	1.464027	1.485366	-1.466	1.466	2.149156	0.021339
May-22	1.9627	3.4279	0.292854	0.535028	-1.4652	1.4652	2.146811	0.242174
Jun-22	0.97445	2.4396	-0.01124	0.387319	-1.46515	1.46515	2.146665	0.398559
Jul-22	0.36167	1.8268	-0.44169	0.261691	-1.46513	1.46513	2.146606	0.703379
Aug-22	0.15311	1.6183	-0.815	0.209059	-1.46519	1.46519	2.146782	1.024055
Sep-22	11.464	12.929	1.059336	1.111565	-1.465	1.465	2.146225	0.052229
Oct-22	0.97872	2.4439	-0.00934	0.388083	-1.4652	1.46518	2.146752	0.397425
	SIM	OBS	LOG SIM	LOG OBS	ERROR	ABS ERR	SQR ERR	LOG ERROR
Nov-22	32.15	33.616	1.507181	1.526546	-1.466	1.466	2.149156	0.019365
Dec-22	0.56056	2.0257	-0.25138	0.306575	-1.46514	1.46514	2.146635	0.557953
Jan-23	33.958	35.424	1.530942	1.549298	-1.466	1.466	2.149156	0.018355
Feb-23	4.8634	6.3301	0.68694	0.801411	-1.4667	1.4667	2.151209	0.114471
Mar-23	15.938	17.404	1.202434	1.240649	-1.466	1.466	2.149156	0.038215
Apr-23	42.529	43.996	1.628685	1.643413	-1.467	1.467	2.152089	0.014728
May-23	36.676	38.142	1.564382	1.581403	-1.466	1.466	2.149156	0.017021
Jun-23	0.57	2.0367	-0.24413	0.308927	-1.4667	1.4667	2.151209	0.553052
Jul-23	0.81646	2.2832	-0.08807	0.358544	-1.46674	1.46674	2.151326	0.446609
Aug-23	0.56347	2.0302	-0.24913	0.307539	-1.46673	1.46673	2.151297	0.556668
Sep-23	0.21298	1.6797	-0.67166	0.225232	-1.46672	1.46672	2.151268	0.896893
Oct-23	0.89564	2.3624	-0.04787	0.373353	-1.46676	1.46676	2.151385	0.42122
Nov-23	45.678	47.145	1.659707	1.673436	-1.467	1.467	2.152089	0.013729
Dec-23	21.896	23.363	1.340365	1.368529	-1.467	1.467	2.152089	0.028164

Jan-24	11.558	13.026	1.062883	1.114811	-1.468	1.468	2.155024	0.051928
Feb-24	7.2895	8.7578	0.862698	0.942395	-1.4683	1.4683	2.155905	0.079697
Mar-24	28.637	30.106	1.456928	1.478653	-1.469	1.469	2.157961	0.021726
Apr-24	32.535	34.004	1.512351	1.53153	-1.469	1.469	2.157961	0.019179
May-24	19.555	21.024	1.291258	1.322715	-1.469	1.469	2.157961	0.031458
Jun-24	1.7915	3.2597	0.253217	0.513178	-1.4682	1.4682	2.155611	0.259961
Jul-24	0.32843	1.7966	-0.48356	0.254451	-1.46817	1.46817	2.155523	0.738009
Aug-24	45.189	46.657	1.655033	1.668917	-1.468	1.468	2.155024	0.013884
Sep-24	0.61184	2.08	-0.21336	0.318063	-1.46816	1.46816	2.155494	0.531425
Oct-24	1.0884	2.5566	0.036789	0.407663	-1.4682	1.4682	2.155611	0.370874
Nov-24	9.7313	11.199	0.988171	1.049179	-1.4677	1.4677	2.154143	0.061008
Dec-24	5.7169	7.1852	0.757161	0.856439	-1.4683	1.4683	2.155905	0.099278
Jan-25	11.905	13.375	1.075729	1.126294	-1.47	1.47	2.1609	0.050564
Feb-25	8.5558	10.026	0.932261	1.001128	-1.4702	1.4702	2.161488	0.068867
Mar-25	3.3091	4.7791	0.51971	0.679346	-1.47	1.47	2.1609	0.159636
Apr-25	5.4188	6.8888	0.733903	0.838144	-1.47	1.47	2.1609	0.10424
May-25	3.1671	4.637	0.500662	0.666237	-1.4699	1.4699	2.160606	0.165575
Jun-25	1.1737	2.6437	0.069557	0.422212	-1.47	1.47	2.1609	0.352655
Jul-25	0.93202	2.402	-0.03057	0.380573	-1.46998	1.46998	2.160841	0.411148
Aug-25	1.0188	2.4888	0.008089	0.39599	-1.47	1.47	2.1609	0.387901
Sep-25	1.0485	2.5184	0.020568	0.401125	-1.4699	1.4699	2.160606	0.380556
Oct-25	5.5129	6.9829	0.74138	0.844036	-1.47	1.47	2.1609	0.102656
Nov-25	15.918	17.388	1.201889	1.24025	-1.47	1.47	2.1609	0.038361
Dec-25	17.751	19.221	1.249223	1.283776	-1.47	1.47	2.1609	0.034553
Jan-26	23.939	25.411	1.379106	1.405022	-1.472	1.472	2.166784	0.025916
	SIM	**OBS**	**LOG SIM**	**LOG OBS**	**ERROR**	**ABS ERR**	**SQR ERR**	**LOG ERROR**
Feb-26	21.879	23.351	1.340027	1.368305	-1.472	1.472	2.166784	0.028278
Mar-26	8.8139	10.286	0.945168	1.012247	-1.4721	1.4721	2.167078	0.067078
Apr-26	13.763	15.235	1.138713	1.182842	-1.472	1.472	2.166784	0.044129
May-26	4.8499	6.3215	0.685733	0.80082	-1.4716	1.4716	2.165607	0.115087
Jun-26	3.6182	5.0898	0.558493	0.706701	-1.4716	1.4716	2.165607	0.148208
Jul-26	9.661	11.133	0.985022	1.046612	-1.472	1.472	2.166784	0.06159
Aug-26	13.053	14.524	1.11571	1.162086	-1.471	1.471	2.163841	0.046376
Sep-26	12.885	14.357	1.110084	1.157064	-1.472	1.472	2.166784	0.046979
Oct-26	17.547	19.019	1.244203	1.279188	-1.472	1.472	2.166784	0.034985
Nov-26	28.353	29.825	1.452599	1.47458	-1.472	1.472	2.166784	0.021981
Dec-26	29.785	31.256	1.473998	1.494933	-1.471	1.471	2.163841	0.020936
Jan-27	35.973	37.447	1.555977	1.573417	-1.474	1.474	2.172676	0.01744
Feb-27	35.203	36.676	1.54658	1.564382	-1.473	1.473	2.169729	0.017802
Mar-27	20.848	22.321	1.319064	1.348714	-1.473	1.473	2.169729	0.029649
Apr-27	26.198	27.671	1.418268	1.442025	-1.473	1.473	2.169729	0.023757
May-27	12.021	13.494	1.079941	1.130141	-1.473	1.473	2.169729	0.0502
Jun-27	16.053	17.527	1.205556	1.243708	-1.474	1.474	2.172676	0.038151
Jul-27	21.695	23.168	1.33636	1.364889	-1.473	1.473	2.169729	0.028529

Aug-27	25.087	26.56	1.399449	1.424228	-1.473	1.473	2.169729	0.024779
Sep-27	25.32	26.793	1.403464	1.428021	-1.473	1.473	2.169729	0.024558
Oct-27	29.581	31.054	1.471013	1.492118	-1.473	1.473	2.169729	0.021105
Nov-27	40.788	42.261	1.610532	1.62594	-1.473	1.473	2.169729	0.015407
Dec-27	41.819	43.292	1.621374	1.636408	-1.473	1.473	2.169729	0.015034
Jan-28	48.007	49.483	1.681305	1.694456	-1.476	1.476	2.178576	0.013151
Feb-28	28.345	29.82	1.452476	1.474508	-1.475	1.475	2.175625	0.022031
Mar-28	19.925	21.4	1.299398	1.330414	-1.475	1.475	2.175625	0.031015
Apr-28	17.646	19.121	1.246646	1.281511	-1.475	1.475	2.175625	0.034864
May-28	12.621	14.096	1.101094	1.149096	-1.475	1.475	2.175625	0.048002
Jun-28	1.3138	2.789	0.118529	0.445449	-1.4752	1.4752	2.176215	0.326919
Jul-28	0.64968	2.1248	-0.1873	0.327318	-1.47512	1.47512	2.175979	0.514619
Aug-28	0.36978	1.8449	-0.43206	0.265973	-1.47512	1.47512	2.175979	0.698029
Sep-28	6.7515	8.2267	0.8294	0.915226	-1.4752	1.4752	2.176215	0.085825
Oct-28	0.27439	1.7495	-0.56163	0.242914	-1.47511	1.47511	2.17595	0.804546
Nov-28	1.1557	2.6309	0.062845	0.420104	-1.4752	1.4752	2.176215	0.357259
Dec-28	2.2232	3.6983	0.346979	0.568002	-1.4751	1.4751	2.17592	0.221024
Jan-29	11.18	12.658	1.048442	1.102365	-1.478	1.478	2.184484	0.053923
Feb-29	4.5314	6.0086	0.656232	0.778773	-1.4772	1.4772	2.18212	0.122541
Mar-29	6.437	7.9141	0.808684	0.898402	-1.4771	1.4771	2.181824	0.089718
Apr-29	44.028	45.505	1.643729	1.658059	-1.477	1.477	2.181529	0.01433
May-29	2.3787	3.8559	0.37634	0.586126	-1.4772	1.4772	2.18212	0.209786
Jun-29	0.51041	1.9876	-0.29208	0.298329	-1.47719	1.47719	2.18209	0.59041
	SIM	**OBS**	**LOG SIM**	**LOG OBS**	**ERRO R**	**ABS ERR**	**SQR ERR**	**LOG ERROR**
Jul-29	0.45675	1.9339	-0.34032	0.286434	-1.47715	1.47715	2.181972	0.626755
Aug-29	7.4902	8.9674	0.874493	0.952667	-1.4772	1.4772	2.18212	0.078173
Sep-29	0.95331	2.4305	-0.02077	0.385696	-1.47719	1.47719	2.18209	0.406461
Oct-29	2.5298	4.0069	0.403086	0.602809	-1.4771	1.4771	2.181824	0.199722
Nov-29	31.838	33.315	1.502946	1.52264	-1.477	1.477	2.181529	0.019694
Dec-29	1.1734	2.6505	0.069446	0.423328	-1.4771	1.4771	2.181824	0.353882
Jan-30	14.079	15.558	1.148572	1.191954	-1.479	1.479	2.187441	0.043382
Feb-30	8.7245	10.204	0.940741	1.00877	-1.4795	1.4795	2.18892	0.06803
Mar-30	3.4848	4.9639	0.542178	0.695823	-1.4791	1.4791	2.187737	0.153645
Apr-30	25.31	26.789	1.403292	1.427957	-1.479	1.479	2.187441	0.024664
May-30	16.405	17.884	1.214976	1.252465	-1.479	1.479	2.187441	0.037488
Jun-30	0.36745	1.8466	-0.4348	0.266373	-1.47915	1.47915	2.187885	0.701175
Jul-30	0.17614	1.6553	-0.75414	0.218877	-1.47916	1.47916	2.187914	0.973019
Aug-30	0.1194	1.5732	-0.923	0.196784	-1.4538	1.4538	2.113534	1.11978
Sep-30	0.90758	2.3867	-0.04212	0.377798	-1.47912	1.47912	2.187796	0.419913
Oct-30	0.86637	2.3455	-0.0623	0.370235	-1.47913	1.47913	2.187826	0.432532
Nov-30	11.85	13.33	1.073718	1.12483	-1.48	1.48	2.1904	0.051112
Dec-30	50.629	52.108	1.704399	1.716904	-1.479	1.479	2.187441	0.012505
Jan-31	36.108	37.589	1.557603	1.575061	-1.481	1.481	2.193361	0.017457
Feb-31	43.299	44.781	1.636478	1.651094	-1.482	1.482	2.196324	0.014616

Mar-31	47.046	48.527	1.672523	1.685983	-1.481	1.481	2.193361	0.013461
Apr-31	14.316	15.797	1.155822	1.198575	-1.481	1.481	2.193361	0.042753
May-31	19.8	21.281	1.296665	1.327992	-1.481	1.481	2.193361	0.031327
Jun-31	0.5593	2.0404	-0.25236	0.309715	-1.4811	1.4811	2.193657	0.56207
Jul-31	0.040848	1.4529	-1.38883	0.162236	-1.41205	1.412052	1.993891	1.551065
Aug-31	0.15391	1.622	-0.81273	0.210051	-1.46809	1.46809	2.155288	1.022784
Sep-31	0.95791	2.439	-0.01868	0.387212	-1.48109	1.48109	2.193628	0.405887
Oct-31	28.398	29.879	1.453288	1.475366	-1.481	1.481	2.193361	0.022078
Nov-31	10.741	12.222	1.031045	1.087142	-1.481	1.481	2.193361	0.056098
Dec-31	44.38	45.861	1.647187	1.661444	-1.481	1.481	2.193361	0.014256
Jan-32	10.389	11.872	1.016574	1.074524	-1.483	1.483	2.199289	0.05795
Feb-32	11.126	12.609	1.046339	1.100681	-1.483	1.483	2.199289	0.054342
Mar-32	40.771	42.254	1.610351	1.625868	-1.483	1.483	2.199289	0.015516
Apr-32	85.637	87.12	1.932661	1.940118	-1.483	1.483	2.199289	0.007456
May-32	13.185	14.668	1.12008	1.166371	-1.483	1.483	2.199289	0.046291
Jun-32	0.44074	1.9238	-0.35582	0.28416	-1.48306	1.48306	2.199467	0.639977
Jul-32	0.45755	1.9406	-0.33956	0.287936	-1.48305	1.48305	2.199437	0.627497
	SIM	**OBS**	**LOG SIM**	**LOG OBS**	**ERROR**	**ABS ERR**	**SQR ERR**	**LOG ERROR**
Aug-32	12.396	13.879	1.093282	1.142358	-1.483	1.483	2.199289	0.049077
Sep-32	0.43048	1.9136	-0.36605	0.281851	-1.48312	1.48312	2.199645	0.647898
Oct-32	12.898	14.381	1.110522	1.157789	-1.483	1.483	2.199289	0.047267
Nov-32	6.6333	8.1163	0.82173	0.909358	-1.483	1.483	2.199289	0.087628
Dec-32	5.5669	7.05	0.745613	0.848189	-1.4831	1.4831	2.199586	0.102576
Jan-33	24.629	26.115	1.391447	1.41689	-1.486	1.486	2.208196	0.025443
Feb-33	19.119	20.604	1.281465	1.313952	-1.485	1.485	2.205225	0.032486
Mar-33	4.3089	5.7943	0.634366	0.763001	-1.4854	1.4854	2.206413	0.128635
Apr-33	30.19	31.676	1.479863	1.50073	-1.486	1.486	2.208196	0.020867
May-33	4.1025	5.5879	0.613049	0.747249	-1.4854	1.4854	2.206413	0.1342
Jun-33	34.771	36.256	1.541217	1.55938	-1.485	1.485	2.205225	0.018163
Jul-33	0.1542	1.6159	-0.81192	0.208414	-1.4617	1.4617	2.136567	1.02033
Aug-33	12.367	13.852	1.092264	1.141512	-1.485	1.485	2.205225	0.049248
Sep-33	0.71913	2.2045	-0.14319	0.34331	-1.48537	1.48537	2.206324	0.486503
Oct-33	11.614	13.1	1.064982	1.117271	-1.486	1.486	2.208196	0.052289
Nov-33	1.3108	2.7962	0.117536	0.446568	-1.4854	1.4854	2.206413	0.329032
Dec-33	0.98613	2.4715	-0.00607	0.392961	-1.48537	1.48537	2.206324	0.399026
Jan-34	0.49927	1.9869	-0.30166	0.298176	-1.48763	1.48763	2.213043	0.599841
Feb-34	13.604	15.091	1.133667	1.178718	-1.487	1.487	2.211169	0.045051
Mar-34	1.5379	3.0255	0.186928	0.480797	-1.4876	1.4876	2.212954	0.293869
Apr-34	2.7029	4.1905	0.43183	0.622266	-1.4876	1.4876	2.212954	0.190436
May-34	15.009	16.497	1.176352	1.217405	-1.488	1.488	2.214144	0.041053
Jun-34	3.4947	4.9823	0.54341	0.69743	-1.4876	1.4876	2.212954	0.15402
Jul-34	3.4415	4.9292	0.536748	0.692776	-1.4877	1.4877	2.213251	0.156029
Aug-34	0.13063	1.5787	-0.88396	0.1983	-1.44807	1.44807	2.096907	1.082257
Sep-34	0.91182	2.3994	-0.04009	0.380103	-1.48758	1.48758	2.212894	0.420194

Oct-34	10.409	11.897	1.017409	1.075437	-1.488	1.488	2.214144	0.058028
Nov-34	8.5718	10.059	0.933072	1.002555	-1.4872	1.4872	2.211764	0.069483
Dec-34	17.479	18.966	1.242517	1.277976	-1.487	1.487	2.211169	0.035459
Jan-35	36.123	37.613	1.557784	1.575338	-1.49	1.49	2.2201	0.017554
Feb-35	51.593	53.083	1.712591	1.724955	-1.49	1.49	2.2201	0.012365
Mar-35	3.7637	5.2537	0.575615	0.720465	-1.49	1.49	2.2201	0.14485
Apr-35	0.35364	1.8436	-0.45144	0.265667	-1.48996	1.48996	2.219981	0.717105
May-35	0.99761	2.4876	-0.00104	0.395781	-1.48999	1.48999	2.22007	0.39682
Jun-35	1.0288	2.5187	0.012331	0.401176	-1.4899	1.4899	2.219802	0.388845
Jul-35	0.018623	1.439	-1.72995	0.158061	-1.42038	1.420377	2.017471	1.888011
Aug-35	0.17272	1.6361	-0.76266	0.21381	-1.46338	1.46338	2.141481	0.976467
Sep-35	0.19413	1.6666	-0.71191	0.221831	-1.4725	1.47247	2.168168	0.933739
	SIM	**OBS**	**LOG SIM**	**LOG OBS**	**ERROR**	**ABS ERR**	**SQR ERR**	**LOG ERROR**
Oct-35	0.18188	1.6491	-0.74022	0.217247	-1.46722	1.46722	2.152735	0.957462
Nov-35	0.31762	1.8076	-0.49809	0.257102	-1.48998	1.48998	2.22004	0.755194
Dec-35	0.19732	1.6712	-0.70483	0.223028	-1.47388	1.47388	2.172322	0.927857
Jan-36	0.06508	1.4809	-1.18655	0.170526	-1.41582	1.41582	2.004546	1.357078
Feb-36	25.222	26.715	1.40178	1.426755	-1.493	1.493	2.229049	0.024976
Mar-36	60.491	61.983	1.781691	1.792273	-1.492	1.492	2.226064	0.010582
Apr-36	44.549	46.041	1.648838	1.663145	-1.492	1.492	2.226064	0.014307
May-36	6.5878	8.0799	0.81874	0.907406	-1.4921	1.4921	2.226362	0.088666
Jun-36	16.533	18.025	1.218352	1.255875	-1.492	1.492	2.226064	0.037524
Jul-36	0.31641	1.8086	-0.49975	0.257343	-1.49219	1.49219	2.226631	0.757092
Aug-36	0.63343	2.1256	-0.1983	0.327482	-1.49217	1.49217	2.226571	0.525783
Sep-36	0.58748	2.0797	-0.23101	0.318001	-1.49222	1.49222	2.226721	0.549008
Oct-36	0.63029	2.1225	-0.20046	0.326848	-1.49221	1.49221	2.226691	0.527307
Nov-36	68.277	69.769	1.834274	1.843662	-1.492	1.492	2.226064	0.009388
Dec-36	4.7714	6.2636	0.678646	0.796824	-1.4922	1.4922	2.226661	0.118178
Jan-37	12.491	13.986	1.096597	1.145694	-1.495	1.495	2.235025	0.049096
Feb-37	7.605	9.0999	0.881099	0.959037	-1.4949	1.4949	2.234726	0.077937
Mar-37	48.048	49.542	1.681675	1.694974	-1.494	1.494	2.232036	0.013298
Apr-37	50.757	52.252	1.705496	1.718103	-1.495	1.495	2.235025	0.012607
May-37	21.507	23.002	1.33258	1.361766	-1.495	1.495	2.235025	0.029186
Jun-37	1.2698	2.7646	0.103735	0.441632	-1.4948	1.4948	2.234427	0.337897
Jul-37	0.50956	2.0044	-0.2928	0.301984	-1.49484	1.49484	2.234547	0.594789
Aug-37	0.51596	2.0108	-0.28738	0.303369	-1.49484	1.49484	2.234547	0.590753
Sep-37	0.9719	2.4667	-0.01238	0.392116	-1.4948	1.4948	2.234427	0.404495
Oct-37	2.1806	3.6755	0.338576	0.565316	-1.4949	1.4949	2.234726	0.22674
Nov-37	10.183	11.678	1.007876	1.067368	-1.495	1.495	2.235025	0.059493
Dec-37	22.37	23.865	1.349666	1.377761	-1.495	1.495	2.235025	0.028095
Jan-38	38.727	40.225	1.588014	1.604496	-1.498	1.498	2.244004	0.016482
Feb-38	54.593	56.09	1.737137	1.748885	-1.497	1.497	2.241009	0.011748
Mar-38	29.149	30.646	1.464624	1.486374	-1.497	1.497	2.241009	0.02175
Apr-38	34.55	36.048	1.538448	1.556881	-1.498	1.498	2.244004	0.018433

May-38	16.983	18.48	1.230014	1.266702	-1.497	1.497	2.241009	0.036688
Jun-38	17.958	19.455	1.254258	1.289031	-1.497	1.497	2.241009	0.034773
Jul-38	20.417	21.914	1.309992	1.340722	-1.497	1.497	2.241009	0.03073
Aug-38	20.689	22.186	1.315739	1.346079	-1.497	1.497	2.241009	0.03034
Sep-38	12.057	13.554	1.081239	1.132067	-1.497	1.497	2.241009	0.050828
Oct-38	8.3061	9.8035	0.919397	0.991381	-1.4974	1.4974	2.242207	0.071984
Nov-38	18.714	20.211	1.272167	1.305588	-1.497	1.497	2.241009	0.033421
	SIM	**OBS**	**LOG SIM**	**LOG OBS**	**ERRO R**	**ABS ERR**	**SQR ERR**	**LOG ERROR**
Dec-38	19.949	21.447	1.299921	1.331367	-1.498	1.498	2.244004	0.031445
Jan-39	21.579	23.079	1.334031	1.363217	-1.5	1.5	2.25	0.029186
Feb-39	0.12393	1.5566	-0.90682	0.192177	-1.43267	1.43267	2.052543	1.099001
Mar-39	1.4889	2.9889	0.172866	0.475511	-1.5	1.5	2.25	0.302646
Apr-39	4.5605	6.0605	0.659012	0.782508	-1.5	1.5	2.25	0.123496
May-39	3.7621	5.2621	0.57543	0.721159	-1.5	1.5	2.25	0.145729
Jun-39	3.9112	5.4113	0.59231	0.733302	-1.5001	1.5001	2.2503	0.140992
Jul-39	17.774	19.274	1.249785	1.284972	-1.5	1.5	2.25	0.035187
Aug-39	23.913	25.413	1.378634	1.405056	-1.5	1.5	2.25	0.026422
Sep-39	26.948	28.448	1.430527	1.454052	-1.5	1.5	2.25	0.023525
Oct-39	29.537	31.038	1.470366	1.491894	-1.501	1.501	2.253001	0.021527
Nov-39	39.073	40.573	1.591877	1.608237	-1.5	1.5	2.25	0.01636
Dec-39	38.541	40.041	1.585923	1.602505	-1.5	1.5	2.25	0.016582
Jan-40	43.112	44.614	1.634598	1.649471	-1.502	1.502	2.256004	0.014873
Feb-40	39.891	41.393	1.600875	1.616927	-1.502	1.502	2.256004	0.016052
Mar-40	24.752	26.254	1.39361	1.419195	-1.502	1.502	2.256004	0.025585
Apr-40	28.562	30.065	1.455789	1.478061	-1.503	1.503	2.259009	0.022273
May-40	12.69	14.193	1.103462	1.152074	-1.503	1.503	2.259009	0.048613
Jun-40	15.075	16.578	1.178257	1.219532	-1.503	1.503	2.259009	0.041275
Jul-40	19.13	20.633	1.281715	1.314562	-1.503	1.503	2.259009	0.032847
Aug-40	20.905	22.407	1.32025	1.350384	-1.502	1.502	2.256004	0.030134
Sep-40	19.329	20.831	1.286209	1.31871	-1.502	1.502	2.256004	0.032501
Oct-40	22.164	23.667	1.345648	1.374143	-1.503	1.503	2.259009	0.028495
Nov-40	31.454	32.957	1.497676	1.517948	-1.503	1.503	2.259009	0.020272
Dec-40	31.168	32.67	1.493709	1.514149	-1.502	1.502	2.256004	0.02044
Jan-41	35.738	37.243	1.55313	1.571045	-1.505	1.505	2.265025	0.017914
Feb-41	1.0653	2.5709	0.027472	0.410085	-1.5056	1.5056	2.266831	0.382613
Mar-41	43.774	45.28	1.641216	1.655906	-1.506	1.506	2.268036	0.01469
Apr-41	32.272	33.777	1.508826	1.528621	-1.505	1.505	2.265025	0.019795
May-41	2.5331	4.0387	0.403652	0.606242	-1.5056	1.5056	2.266831	0.202589
Jun-41	0.64066	2.1463	-0.19337	0.33169	-1.50564	1.50564	2.266952	0.525063
Jul-41	0.37804	1.8836	-0.42246	0.274989	-1.50556	1.50556	2.266711	0.697451
Aug-41	24.808	26.314	1.394592	1.420187	-1.506	1.506	2.268036	0.025595
Sep-41	0.6096	2.1152	-0.21496	0.325351	-1.5056	1.5056	2.266831	0.540306
Oct-41	0.48415	1.9897	-0.31502	0.298788	-1.50555	1.50555	2.266681	0.613808
Nov-41	27.157	28.662	1.433882	1.457306	-1.505	1.505	2.265025	0.023425

Dec-41	24.591	26.097	1.390776	1.416591	-1.506	1.506	2.268036	0.025814
Jan-42	9.6775	11.186	0.985763	1.048675	-1.5085	1.5085	2.275572	0.062912
Feb-42	0.86613	2.3746	-0.06242	0.37559	-1.50847	1.50847	2.275482	0.438007
Mar-42	2.9378	4.4463	0.468022	0.647999	-1.5085	1.5085	2.275572	0.179977
Apr-42	32.997	34.506	1.518474	1.537895	-1.509	1.509	2.277081	0.01942
	SIM	**OBS**	**LOG SIM**	**LOG OBS**	**ERRO R**	**ABS ERR**	**SQR ERR**	**LOG ERROR**
May-42	1.4867	2.9953	0.172223	0.47644	-1.5086	1.5086	2.275874	0.304217
Jun-42	0.6168	2.1253	-0.20986	0.32742	-1.5085	1.5085	2.275572	0.537276
Jul-42	0.69956	2.2081	-0.15518	0.344019	-1.50854	1.50854	2.275693	0.499194
Aug-42	0.4241	1.9326	-0.37253	0.286142	-1.5085	1.5085	2.275572	0.658674
Sep-42	0.40399	1.9125	-0.39363	0.281601	-1.50851	1.50851	2.275602	0.675231
Oct-42	0.86081	2.3693	-0.06509	0.37462	-1.50849	1.50849	2.275542	0.439713
Nov-42	63.017	64.526	1.799458	1.809735	-1.509	1.509	2.277081	0.010277
Dec-42	27.358	28.866	1.437084	1.460387	-1.508	1.508	2.274064	0.023302
Jan-43	85.727	87.238	1.933118	1.940706	-1.511	1.511	2.283121	0.007588
Feb-43	22.428	23.94	1.350791	1.379124	-1.512	1.512	2.286144	0.028334
Mar-43	3.7202	5.2317	0.570566	0.718643	-1.5115	1.5115	2.284632	0.148077
Apr-43	29.051	30.562	1.463161	1.485182	-1.511	1.511	2.283121	0.022021
May-43	1.9038	3.4154	0.279621	0.533442	-1.5116	1.5116	2.284935	0.25382
Jun-43	0.91556	2.4271	-0.03831	0.385088	-1.51154	1.51154	2.284753	0.423401
Jul-43	0.32604	1.8143	-0.48673	0.258709	-1.48826	1.48826	2.214918	0.745438
Aug-43	0.16794	1.6058	-0.77485	0.205691	-1.43786	1.43786	2.067441	0.980537
Sep-43	11.405	12.916	1.057095	1.111128	-1.511	1.511	2.283121	0.054033
Oct-43	0.91983	2.4314	-0.03629	0.385856	-1.51157	1.51157	2.284844	0.422149
Nov-43	32.091	33.603	1.506383	1.526378	-1.512	1.512	2.286144	0.019995
Dec-43	0.50167	2.0132	-0.29958	0.303887	-1.51153	1.51153	2.284723	0.603469
Jan-44	33.897	35.412	1.530161	1.54915	-1.515	1.515	2.295225	0.018989
Feb-44	4.633	6.1474	0.665862	0.788691	-1.5144	1.5144	2.293407	0.122829
Mar-44	15.877	17.392	1.200768	1.24035	-1.515	1.515	2.295225	0.039581
Apr-44	42.469	43.984	1.628072	1.643295	-1.515	1.515	2.295225	0.015223
May-44	36.615	38.13	1.563659	1.581267	-1.515	1.515	2.295225	0.017608
Jun-44	0.50971	2.0241	-0.29268	0.306232	-1.51439	1.51439	2.293377	0.598909
Jul-44	0.75616	2.2706	-0.12139	0.356141	-1.51444	1.51444	2.293529	0.477527
Aug-44	0.50317	2.0176	-0.29829	0.304835	-1.51443	1.51443	2.293498	0.60312
Sep-44	0.21677	1.6671	-0.664	0.221962	-1.45033	1.45033	2.103457	0.885962
Oct-44	0.83535	2.3498	-0.07813	0.371031	-1.51445	1.51445	2.293559	0.449162
Nov-44	45.618	47.133	1.659136	1.673325	-1.515	1.515	2.295225	0.014189
Dec-44	21.836	23.351	1.339173	1.368305	-1.515	1.515	2.295225	0.029132
Jan-45	11.495	13.013	1.060509	1.114377	-1.518	1.518	2.304324	0.053868
Feb-45	7.4898	9.0077	0.87447	0.954614	-1.5179	1.5179	2.30402	0.080144
Mar-45	28.575	30.093	1.455986	1.478465	-1.518	1.518	2.304324	0.022479
Apr-45	32.473	33.991	1.511522	1.531364	-1.518	1.518	2.304324	0.019842

	SIM	OBS	LOG SIM	LOG OBS	ERRO R	ABS ERR	SQR ERR	LOG ERROR
May-45	19.493	21.011	1.289879	1.322447	-1.518	1.518	2.304324	0.032568
Jun-45	1.7288	3.2467	0.237745	0.511442	-1.5179	1.5179	2.30402	0.273697
Jul-45	0.30914	1.7837	-0.50984	0.251322	-1.47456	1.47456	2.174327	0.761167
Aug-45	45.126	46.644	1.654427	1.668796	-1.518	1.518	2.304324	0.014369
Sep-45	0.54916	2.0671	-0.2603	0.315361	-1.51794	1.51794	2.304142	0.575663
Oct-45	1.0258	2.5437	0.011063	0.405466	-1.5179	1.5179	2.30402	0.394403
Nov-45	9.6686	11.187	0.985364	1.048714	-1.5184	1.5184	2.305539	0.06335
Dec-45	5.6543	7.1722	0.752379	0.855652	-1.5179	1.5179	2.30402	0.103274