The University of Nairobi School of Engineering

Environmental Flow Assessment Using HEC-EFM and GIS: A Case Study of Kibos River

A Thesis Submitted in Partial Fulfilment for the Degree of Msc. in Civil Engineering (Environmental Health Engineering Option) in the Department of Civil and Construction Engineering of the University of Nairobi

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DECLARATION

I, the undersigned, declare that this is my original work and has not been presented for the award of a degree in any other University and that all sources of the materials used for the thesis have been duly acknowledged.

Signature ……………………………. Date ………………………….

Wakjira Umetta Wakitolie (F56/64887/2010)

This thesis has been submitted with my approval as the Thesis Supervisor

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Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

BBM	-	Building Block Method
DTM	-	Digital Terrain Model
EF	-	Environmental Flow
EFA	-	Environmental Flow Assessment
EFR	-	Environmental Flow Requirement
EFM	-	Ecosystem Functions Model
GIS	-	Geographic Information System
HEC	-	Hydrologic Engineering Center
IFA	-	Instream Flow Assessment
IFIM	-	Instream Flow Incremental Method
IUCN	-	International Union for Conservation of Nature and Natural Resources
IWRM	-	Integrated Water Resources Management
m.a.m.s.l	-	Meters above Mean Sea Level
U.S.A	-	United States of America
WADA	-	Water and Development Alliance
WRMA	-	Water Resources Management Authority
WUA	-	Wetted Useable Area
BOD5	-	The amount of dissolved oxygen consumed in five days by biological processes breaking down organic matter.

LIST OF APPENDICES

ABSTRACT

Historically, water has been managed from a supply perspective with an emphasis on short-term economic growth from the use of the water. In this respect many municipalities, water service boards and other local authorities strive to supply water in abundance to their community. This has led to unprecedented environmental degradation.

This has been witnessed in the over-consumption of Upper Athi River and Upper Tana River for supply to the City of Nairobi. There is a danger of similar situation recurring on the Kibos River for abstraction to the City of Kisumu. The water-resources planners such as water supply, hydropower, and irrigation engineers, need to give due emphasis to understanding of the need for environmental flows required to maintain the health of the ecosystem of these rivers.

Most of the methods developed so far are project specific or basin specific and cannot be readily applied in Kenya as hydrological and physical characteristics of the rivers/basins for which the methods are developed, are different from that of Kenyan rivers/basins. There is therefore a need to select standard methods and software/s which can be used at national level irrespective of the type and scale of project under consideration. his research has used HEC- Ecological Functioning Model (EFM) an open source software in water resources planning (in the Kenyan context) through modeling of Kisumu Water Supply and Sanitation Long Term Action Plan, using Kibos River as source of water.

The three environmental indicators employed for the research are fish (Labeo, Clarias and Barbus), micro-invertebrates in general and Nyamasaria swamp as wetland.

The methods applied for assessment of risk level are modified method derived from Davies and Humphries (1996) for Risk Levels Assessment based on Modified Key Ecological Variables and the method developed by Tannent in 1976 for identified critical minimum flows required for Fish, Wildlife and Recreation in streams. .

The research has revealed that there will be environmental change on Kibos River due to the proposed intake/diversion weir on Kibos River. It is expected that there will be significant migration of fishes from the affected reach of the river to the reach upstream of the diversion weir and to the river reach downstream of Awach and Kibos confluence. This can only happen if the run-of-river scheme treatment plant is operated at 48,000 m^3/day throughout the year.

If the city is supplied at 36,000 m^3/day as run-of-river scheme and if necessary mitigation measures are taken the water supply project can be compatibly integrated in the ecosystem.

1. INTRODUCTION

1.1 Background

1.1.1 General Background Information

Water is an important part of any ecosystem, both in qualitative and quantitative terms. Reduced water quantity and deteriorated water quality both have serious negative impacts on ecosystems. The water environment has a natural self-cleansing capacity and resilience to water shortages. But when these are exceeded, biodiversity is lost, livelihoods are affected, and natural food sources (e.g. Fish) are damaged and high clean-up and rehabilitation costs result.

Manipulation of the flow regimes of rivers, to provide water when and where people need it, has resulted in a growing deterioration in the condition (health) of riverine ecosystems. The science of environmental, or instream, flow assessments (EFAs or IFAs) has evolved over the last five decades, as a means to help contain, and perhaps to some extent reverse, this degradation (King et al. 2008).

Most studies in Africa concentrate on Minimum Environmental Flow release without giving due consideration for alteration of the Hydrologic regime. Hydrological regimes play a major role in determining the biotic composition, structure, and function of aquatic, wetland, and riparian ecosystem. But human, land and water uses are substantially altering hydrologic regimes around the world (Richter et al.1996). As a result many countries have to address pre and post impact of their project on the environment.

1.1.2 What is Environmental Flow Assessment (EFA) ?

An EFA is an assessment of how much of the original flow regime of a river should continue to flow downstream in order to maintain specified valued features of the riverine ecosystem. It is used to assess how much water could be abstracted from a river without an unacceptable level of degradation of the riverine ecosystem (King et. al 1999).

The goal of environmental flows is to provide a flow regime that is adequate in terms of quantity, quality and timing for the health of the rivers and other aquatic ecosystems (Megan et al. 2003). Most of the time studies concentrate on the quantity (minimum environmental flow) without giving due consideration on the quality and timing. The last two are very important to the health of the river. For example, it might be discovered that floodplains need to be inundated for a certain minimum period to stimulate fish breading. The science of analysing eco-hydro relationships and determination of flows that are required in time and space is called environmental flow assessment. However, it should be noted that provision of environmental flows is not only a scientific question, but also a social, economic and political issue (Shiferaw 2007).

1.1.3 Methods of EFA

Since the 1970's more than 200 methods of EFA are being used all over the world (CRC 2008). It is noteworthy that many methodologies are poorly documented in the mainstream scientific literature (King, 1996 and Islam, 2010). Intensive research into environmental flows is underway in North America, South Africa and Australia, while the field of flow assessments is expanding in Europe and parts of Asia particularly in Australia. However, vast areas of South and Central America, Asia and Africa do not appear to have begun any significant research or application in this field. Certainly, literature pertaining to environmental flows is markedly less available for these regions ***(***King, 1990).

Realistically, the selection of an appropriate environmental flow assessment methodology or methodologies for application in any individual country is likely to be case-specific and primarily limited by the availability of data on the river system of concern, and existing local constraints in terms of time, finances, expertise and logistical support (King et al.1999).

According to IUCN (Dyson et al. 2003) these methods for flow defining can be broadly classified into four categories:

1. Look-up tables
2. Desk top analysis

3. Functional analysis
4. Habitat modelling

A study by King (1999) citied by Islam (2010) showed that the first two methods use hydrological and some hydraulic modelling with some ecological data. In the study it has also been mentioned that the first method is normally used for reconnaissance level of water resources developments, or as a tool within other methodology and the second will be in water-resources developments where no or limited negotiation is involved. Taking the scarcity of resources and information into consideration these two methods are recommended for usage for developing countries, especially if the size of the river basin as well as the scale of the project is small. These methods are briefly described as follows, most are extracts from International Union for Conservation of Nature and Natural Resources publications IUCN (Dyson et al. 2003).

Look-up-Tables: These methods are purely based on hydrological data. They are worldwide most commonly applied methods. They define target river flows based on rule of thumb from simple indices given on developed look-up tables.

Desk Top Analysis: These methods focus in analysis of hydrological data. These methods use existing data such as river flows from gauging stations and/or fish data from regular survey. Upon requirement the methods are open for collection and application of some ecological data at a particular site or sites on a river to supplement existing information. These methods are normally subdivided in three subcategories into those based purely on hydrological data, those that use hydraulic information (such as channel form) and those that employ ecological data. Unlike Look-up-tables the hydrological desk-top analysis methods examine the whole river flow regime rather than pre-derived statistics.

Functional Analysis: These methods build understanding of the functional links between all aspects of the hydrology and ecology of the river system. These methods take a broad view and cover many aspects of the river ecosystem, using hydrological analysis, hydraulic rating information and biological data. They also make significant use of experts. Perhaps the best known is the Building Block Methodology (BBM), developed in South Africa. The basic premise of the BBM is that riverine species are reliant on basic elements (building blocks) of the flow regime, including low flows and floods that maintain the sediment dynamics and geo-morphological structure of the river (Dyson et al. 2003).

Habitat Modelling: All the above three methods have difficulties in relating changes in the flow regime directly to the response of species and communities. Hence methods have been developed that use data on habitat for target species to determine ecological flow requirements. Within the environmental conditions required by a specific freshwater species, it is the physical aspects that are most heavily impacted by changes to the flow regime. The relationship between flow, habitat and species can be described by linking the physical properties of river stretches, e.g. depth and flow velocity, at different measured or modelled flows, with the physical conditions that key animal or plant species require. Once functional relationships between physical habitat and flow have been defined, they can be linked to scenarios of river flow (Dyson et al. 2003).

1.1.4 What is HEC-EFM?

The Ecosystem Functions Model (HEC-EFM) is a planning tool that aids in analysing ecosystem response to changes in flow regime. The Hydrologic Engineering Centre (HEC) of the U.S. Army Corps of Engineers has developed HEC-EFM to enable project teams to visualize existing ecologic conditions, highlighting promising restoration sites, and assess and rank alternatives according to the relative change in ecosystem aspects (HEC, 2009).

Central to HEC-EFM analyses are “functional relationships.” These relationships link characteristics of hydrologic and hydraulic time series (flow and stage) to elements of the ecosystem through combination of four basic criteria: 1) season, 2) flow frequency, 3) duration, and 4) rate of change. There is no limit to the number or category of relationships that may be developed and it has an interface to facilitate entry and inventory of criteria.

1.1.5 Background of Kajulu Water Supply Project

The Kajulu intake was first established in 1922. It is located in the north of Kadero. Kajulu River originates at 1960 m.a.m.s.l in the North East (Kobujoi Village) and at 1940 m.a.m.s.l in the North (Morongiot Village) **(Figure 1-1)**.

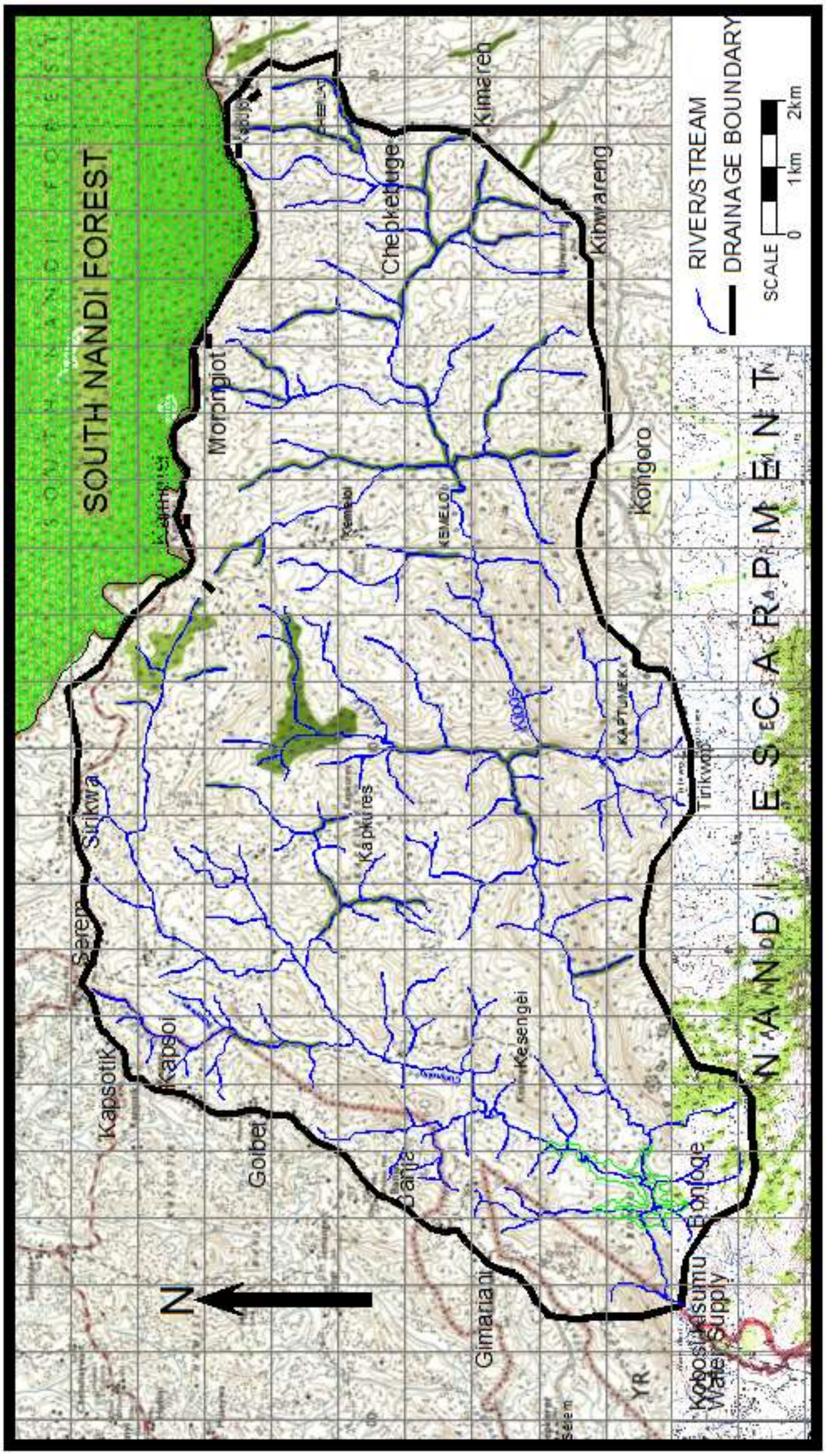


Figure 1-1:Kibos River Catchment

There are two intake sources at Kajulu. According to the Seureca/CAS Report (Kisumu Feasibility Study Report), Kajulu River has a catchment area of approximately 75km^2 upstream of Kajulu Water Intake).

The design capacity of the existing Kajulu works is 2,200 m^3/day while the actual extracted amount is 1,700 m^3/day. The river intake, with provision of a dam upstream of the existing intake, can allow between 120,000 m^3/day to 360,000 m^3/day to be extracted, which was believed to be sufficient to serve the whole of Kisumu municipality and its surrounding market centres up to and beyond year 2031 (Mouchel Parkman, 2008). As per the study, the existing river can also yield up to 36,000 m^3/day of raw water without a dam with over 90% reliability.

As part of its development plan, Lake Victoria South Water Service Board is planning to extract additional 36,000-48,000 m^3/day from the same river without and with impoundment (as option) respectively (Mouchel Parkman, 2008). To this effect several studies have been conducted on the river; however, none of them has carried out any environmental flow assessment before and after implementation of their proposed project, and fall short in clearly mentioning the impact of abstraction of water by the project. Of these studies some have only defined "minimum environmental flow". However, environmental flows are likely to be different from natural flows and are seldom "minimum or average flows".

Kibos River is one of several rivers feeding Lake Victoria from the east. Lake Victoria is the main source of fish for the region. Kibos River could be one of the rivers which provide breeding grounds for fish which are under extinction. The frequent floods could be a means of transporting fish from their breeding ground to the lake. Alteration of the quantity as well as the hydrological regime should therefore be done in a controlled manner. There is a need to maintain the moisture of the river channel as well as inundate the river for a certain minimum period to stimulate fish breeding and transporting from time to time. Thus, consideration of minimum or average flow might not be enough to protect the health of the ecosystem in this respect.

Previous project studies (SEURECA CAS, 2005-2006 and Mouchel Parkman, 2008) concentrated on the quantity (minimum environmental flow) without giving due consideration to the quality and timing. Furthermore, the studies did not carry out reservoir simulation study and thus had not set reservoir operation rule curves. In the absence of reservoir simulation result, it will be difficult to prescribe any Environmental Flow/s as well as minimum environmental flow releases.

Preliminary hydrological analysis and the estimated demand by the two studies show that no water will be released to the downstream reach of the river, which will remain dry for minimum period of 1.5 to 2.0 months. The result of the preliminary analysis is presented in the following table:

Table 1-1: Result of Preliminary Analysis

Proposed Scheme	**Design Discharge (m^3/s)**	**Corresponding % exceedance**
Run-off-River scheme	0.495	90%
Dam Option	0.556	82%

As shown above with the proposed arrangement (by both studies) the project could negatively impact the ecology on downstream reach of the river. Even the flows proposed by the studies for minimum environmental release will not be available.

Pending these proposed flow values, there may be a need to safeguard the river ecosystem through managing waters to meet human and ecological demands. As part of the management plan, determination of EF is prudent and has to be carried out.

There is, however, lack of simplified operational methods and software (selected at National level) to demonstrate the link between environmental flows and ecosystem services. This thesis could be pioneer in the country; its approaches and findings could help the river under consideration in short term time frame and can be repeated in other projects in the Country in the long run.

The study will employ HEC-EFM and GIS software to assess environmental flow.

1.2 Statement of the Problem

Previous project studies (SEURECA CAS, 2005-2006 and Mouchel Parkman, 2008) concentrated on the quantity (minimum environmental flow) without giving due consideration to the quality and timing of river flow. The last two are very important to the health of the river. For example, it might be discovered that floodplains need to be inundated for a certain minimum period to simulate fish breeding.

Furthermore the studies did not carry out reservoir simulation and had not set reservoir rule curves. In the absence of such information, it will be difficult to prescribe any Environmental Flow Assessment. In this regard it is worth noting that for some unknown reason/s, the two studies did not carry out full-fledged hydrological and reservoir simulation studies as well as EFA. The reason/s could be attributed to one or all of the following:

- Lack of funds to carry out EFA
- Lack of understanding towards EFA
- Or the EFA may have been overlooked thinking the small size of the project as well as the catchment area commanded by the intake

Accordingly, prior to the development of EFA, there is need to carry out reservoir simulation study for the dam to be implemented in the future. Once the basic hydrological parameters have been established, EF that can maintain the health of the river and its eco-system are established. The purpose of this flow/s could be as general as maintenance of a ‘healthy’ riverine ecosystem, or as specific as enhancing the survival chances of a threatened fish species.

This task has been carried out using HEC-EFM modelling and GIS software. Furthermore it recommend a way forward on how to address such problems by water resources planners and developers in the future.

1.3 Objectives of the Study

1.3.1 General Objective

The objective of the research is to find environmental flows needed to provide a flow regime that is adequate in terms of quantity and timing for the health of Kajulu River and other aquatic ecosystems.

1.3.2 Specific Objective

The specific objectives of the research are:

- *To provide supplementary hydrological information to the on-going Kajulu Water Supply Development Project*
- *To develop reservoir rule curves*
- *To investigate the impact of Kajulu Water Supply Project on the flow regime of Kajulu River and its perceived consequence using HEC-EFM and GIS*
- *To determine the capability, benefit as well as the limitation of the modeling software in Kenyan context.*
- *To recommend the way forward for undertaking Environmental Flow Assessment in general and Ecological Flow modeling in particular*
- *To generate water research information which could assist in the operation of the system as well as any expansion works in the future.*

1.4 Scope and Limitation of the Study

1.4.1 Scope of the Study

A range of methods have been developed in various countries that can be employed to define ecological flow requirements (Dunbar, 1998). Depending on the complexity of each method, data requirement to define the EF will vary in terms of details and quality. Irrespective of the method/s applied for this research the scope of this study/ thesis had been defined but not limited to the following:

- Organize Data and relevant document collection
- Identify the present state and important issues in Kajulu/Kibos river basin
- Select representative reaches of the river for detailed assessment (accessibility shall be the main criteria while selecting these reaches of the river)
- Conduct targeted data collection
- Perform Hydrological Analysis and Reservoir Simulation
- Data analysis and initial environmental flow recommendations
- Presentation of results and recommendations
- Selection of Environmental Flows

1.4.2 Limitation of the Study

Except the look-up table method, all methods need input from several experts. This is essential for clear and complete undertaking of the eco-system. The researcher has limited knowledge in the field of biology, fishery and etc. To fill such gaps, it has been tried to make the following arrangement:

- A number of literatures have been referred to such that all aspects are covered
- Attempt was made to work with relevant department in the Kenya Marine and Fish Research Institute, Kisumu Office, while developing eco-hydro relationship

In addition to the above limitations, collection of field data such as river cross sections, which are vital for development of stage discharge relationships at estuarine, was difficult. Survey at these sections should have been done at large scale such that it would have been possible to develop practical and reasonable eco-hydro relationship, which is the core engine of the model to be developed. However, for Kisbos no maps were available at such scale. It was difficult and expensive to carry out surveying on the whole river reach (25 km). Thus only two sections have been selected for modelling.

2. LITERATURE REVIEW

2.1 Historical Background

In an international context, the development and application of methodologies for prescribing EFRs (also known as instream flow requirements (IFRs), began as early as the 1950s, in the western U.S.A, with marked progress during the 1970s (King, 1996). Outside the U.S.A., the process by which environmental flow methodologies evolved and became established for use is less apparent, as there is little published information on the topic (Tharme, 1996). In some countries, for instance England, Australia, New Zealand and South Africa, EFAs for rivers only began to gain ground as late as the 1980s. Other parts of the world appear less advanced in the field. This suggests that many countries have either not yet recognised the critical importance of EFAs in the long-term maintenance and sustainability of freshwater systems or have not made such assessments a priority (Tharme, 1996).

Presently, a vast body of formal methodologies exists for prescribing environmental flow needs. Thus, there is no one method as universally accepted method for EFA. All methods are evolving daily. Thus, the methods described in here are not exhaustive.

2.1.1 Methods of Environmental Flow Determination

A range of methods has been developed in various countries that can be employed to define ecological flow requirements (Dunbar, 1998). These methodologies have been developed to estimate the environmental flow requirements of a river as a proxy for answering the question that challenges freshwater ecologists and water resource managers worldwide: “how much water does a river need?” These methodologies vary in levels of data requirements and complexity. The methods for defining flow requirement can be broadly classified into four categories:

1. Look-up tables
2. Desk top analysis
3. Functional analysis

4. Habitat modelling

Each of these methods may involve more or less input from experts and may address all or just parts of the river system. Other classifications of methods have been undertaken (Megan et al. 2003) and (Tharme, 2003) which include more subdivisions, which require complex data inputs as well as use of sophisticated methods of analysis. The use of the result of such analysis may be difficult as stakeholders involved might not fully understand. As a result, it will be difficult to set threshold flows. Thus, selections of methods of analyses as well as interpretation of the results need to be as clear as possible. However, it should be noted that for the sake of simplicity, inputs from experts in other fields should not be overlooked. As long as conditions permit inputs from the following experts need to be considered while modelling (CRC,2008):

- Geo-morphologist
- Riparian specialist
- Sociologists
- Hydraulic Engineer
- Aquatic ecologist
- Hydrologist

However, the requirement of input from the above experts depends on the goal of EFA and the method to be applied. For instance look up method most often will require input from hydrologist and hydraulic engineer and an ecologist from time to time.

Realistically, the selection of an appropriate environmental flow methodology or methodologies for application in any individual country is likely to be case-specific and primarily limited by the availability of data on the river system of concern, and existing local constraints in terms of time, finances, expertise and logistical support (King et al.1999).

The following sections start by describing the above listed methods and finally propose the method to be adopted for this research.

2.1.2 Most Widely Used EFA Methods

King has tried to categorize the EFA methods which are being most widely used (Davis and Hirji, 2003). The category and description of each is presented below.

Hydrological Index Method: Hydrological index methods are mainly desktop approaches relying primarily on historical flow records to make flow recommendations for the future. Little attention is given to the specific nature of the considered river or its biota.

Hydraulic Rating Method: Hydraulic rating methods use the relationship between the flow of a river (discharge) and simple hydraulic characteristics such as water depth, velocity, or wetted perimeter to calculate an acceptable flow. These methods are an improvement on hydrological index methods, since they require measurements of the river channel, and so are more sensitive than the desktop approaches. However, judgment of an acceptable flow is still based more on the physical features of the river rather than on known flow-related needs of the biota.

Expert Panel Method: Expert Panels use a team of experts to make judgments on the flow needs of different aquatic biota.

Prescriptive Holistic Approach: Prescriptive holistic approaches require collection of considerable specific data pertaining to a river and making structured links between flow characteristics of the river and the flow needs of the main biotic groups (fish, vegetation, invertebrates).

A study by King (1999) citied by Islam (2010) showed that the first two methods use hydrological and some hydraulic modelling with some ecological data. In the study, it has also been mentioned that the first method is normally used for reconnaissance level of water resources developments, or as a tool within other methodology and the second is used for water-resources developments where no or limited negotiation is involved. Taking the scarcity of resources and information into consideration these two methods are recommended for usage for developing countries, especially for small size river basins as well as small scale projects.

2.2 Environmental Flow Estimation in Developing Countries

Contrary to developed countries, environmental flow assessment has received little attention in the majority of developing countries. This applies even to semi-arid and arid parts of the world, where the availability, quality and sustainability of freshwater resources play a crucial role in socio-economic development. It is noteworthy that many countries for which EFAs do not seem to be a priority are carrying out intensive water-resource development projects, particularly in the form of river regulation by large dams (McCully, 1996). In some countries however, environmental flow work has been initiated, although it is still in its infancy. In other countries, such as Mozambique, Argentina and Zimbabwe, interest in environmental water allocations appears to be growing (Tharme, 1996).

As indicated in most publications on EFA, South Africa represents one of the few developing countries that have invested considerable resources in environmental flow assessment, albeit only in the past ten years or so. The situation in Kenya is like most of African countries and EFA is at its infant stage.

2.3 Existing Methods and Models

2.3.1 Desktop EFA Models

Desk-top analysis methods use existing data such as river flows from gauging stations and/or fish data from regular surveys. If needed, some data may be collected at a particular site or sites on a river to supplement existing information. Desk-top analysis methods can be sub-divided into those based purely on hydrological data, those that use hydraulic information (such as channel form) and those that employ ecological data.

2.3.1.1 Hydrologic Methods

Hydrological desk-top analysis methods examine the whole river flow regime rather than pre-derived statistics. A fundamental principle is to maintain integrity, natural seasonality and variability of flows, including floods and low flows. Most scholars in the field agree that there has not been enough research to relate the flow statistics to specific elements of the ecosystem.

From an ecological perspective, this type of methodology is especially simplistic in that it does not adequately address the dynamic and variable nature of the hydrological regime (King, 2008). The methodologies are also highly limited, in the majority of applications, by the absence of ecological information as input. This restricts their flexibility, degree of resolution, and scope for use relative to other types of methodology, as well as rendering them open to considerable criticism. There is also the risk that the low resolution, single figures that most often constitute the output will be routinely applied across different countries, geographic regions and river types, without sufficient understanding of the ecological implications. Hence, it is suggested that professional judgement is essential when such methodologies are employed. Such disadvantages render hydrological methodologies appropriate only at a planning level, and in cases that are not high profile, where no negotiation is involved in the decision-making process. They should also be applied with extreme caution in countries or regions with hydrological regimes that differ vastly from their place of origin. An example of a hydrological desk-top analysis method is the Richter method (Richter, 1996).

2.3.1.2 Hydraulic Methods

Hydraulic rating methods form another important group of desk-top analysis techniques. There are two main groups of methodologies, founded on a habitat-discharge relationship, which progressively evolved from hydrology, hydraulics and ecology, namely *hydraulic rating* and *habitat rating methodologies* (Kings 2008, Trihey & Stalnaker 1985)

Hydraulic rating methodologies (wetted perimeter Methods as used in North America) measure changes in various single river hydraulic variables such as wetted perimeter or maximum depth, at a single cross-section. These provide simple indices of available habitat in a river at a given discharge.

In hydraulic rating, some researchers have highlighted the problems of trying to identify threshold discharges below which wetted perimeter declines rapidly. Given this limitation, the method is more appropriate to support scenario-based decision-making and water allocation negotiations than to determine an ecological threshold.

The latter approach (*habitat rating methodologies*) integrates hydraulic data, collected from multiple cross-sections, with biological data on the physical habitat requirements of the biota. In some cases limited field surveys are undertaken while in others the existing stage-discharge curves from river gauging stations are used.

Desk-top analysis methods that use Ecological Data tend to be based on statistical techniques that relate independent variables, such as flow, to biotic dependent variables, such as population numbers or indices of community structure calculated from species lists. The advantage of this type of method is that it directly addresses the two areas of concern (flow and ecology), and directly takes into account the nature of the river in question.

In general, Kings (2008) states those hydraulic rating methodologies can be considered an advance over purely hydrology-based ones in that they incorporate ecologically-based information on the in-stream. They enable a fairly rapid, though simple, assessment of flows for the maintenance of such habitat areas for requirements such as invertebrate production, fish spawning and passage. They are also sufficiently flexible to be applied to many aquatic species and activities, as well as being only low to moderately resource-intensive. Furthermore, they can be used as reconnaissance methods at a regional or catchment-wide level, on all sizes and types of streams.

2.3.2 Habitat Modelling

As discussed above, difficulties exist in relating changes in the flow regime directly to the response of species and communities. Hence methods have been developed that use data on habitat for target species to determine ecological flow requirements. Within the environmental conditions required by a specific freshwater species, it is the physical aspects that are most heavily impacted by changes to the flow regime. The relationship between flow, habitat and species can be described by linking the physical properties of river stretches, e.g. depth and flow velocity, at different measured or modelled flows, with the physical conditions that key animal or plant species require (CRC,2008). Once functional relationships between physical habitat and flow have been defined, they can be linked to scenarios of river flow.

The first step in formulating this method for rivers was published in 1976. This quickly led to the more formal description of a computer model called PHABSIM (Physical Habitat Simulation) by the US Fish and Wildlife Service. Over the years, the model evolved into different types of and more advanced models. Unlike the traditionally operated one dimensional hydraulic model this model uses multi-dimensional hydraulic model. Recently developed computer models are capable of modelling and analysing combined relationships (analysing one or more eco-hydro relationships).

The physical habitat modelling method has now been adapted for use in many countries while other countries have independently developed similar methods. Thus, it is high time to test some of these models and adopt the most appropriate one at national level.

Physical habitat modelling has been used to estimate the effects, in terms of usable physical habitat, of historical or future anticipated changes in flow caused by abstraction or dam construction.

2.4 EFM-Ecosystem Functioning Modelling

HEC-Ecological Functioning Model (HEC-EFM) uses hydrological and hydraulic data as main parameters for simulation. The habitat flow requirements are set and used as surrogate for copying breeding and feeding behaviour of each species and taxa considered. Like that of habitat models this model is used to estimate the effects, in terms of usable physical habitat, of historical or future anticipated changes in flow caused by abstraction or dam construction. HEC-Ecological Functioning model is somehow closer to the Habitat model however, the model does not consider other parameters such as wetted perimeter or velocity but rather uses flow and water depth only (HEC, 2009). In general, HEC-EFM is more advanced and complex than those of purely hydrological/Hydraulic methods but is inferior to other Physical Habitat Models.

2.5 Fish Ecology

2.5.1 Background

It was difficult to carry out fully-fledged literature review on fish as it is vast and beyond the scope of the thesis. Thus, prior to commencement of review of literatures on fresh water fish ecology it has been tried to assess the type of fishes in nearby tributaries of Lake Victoria in general and in Kibos River in particular. This has been done with the assistance from Kenya Marine and Fish Research Centre Kisumu Branch. They have identified the following fishes which are proved to exist in Kibos River.

- Lebeo
- Barbus
- Clarias
- Tilapia even though in small quantities

The literature review has concentrated or focused on these fishes. It should also be noted that it is difficult and is beyond the scope the thesis to review the biology of these fishes, thus only the life history and reproductive cycles, which are more vital for modelling, have been reviewed.

2.5.2 Fish Ecology General

Due to change in the environmental conditions fish stock is reducing at an alarming rate in the tributaries of Lake Victoria. It has been observed with interest that certain fish species have decreased in numbers over the years; within the inland waters the decline has been at a rate which if left unchecked, will eventually cause total disappearance of the species concerned. Thus, some species have been termed “endangered”. Among them are Labeo, Schilbe, Alestes, Clarias and Barbus spp. (David 1981).

Thus, of all species of fishes in the river these deserve consideration for conservation, thus selected as indicator for modelling purposes.

2.5.3 Fish in Kibos Watershed

2.5.3.1 Labeo (Rock Dwellers)

The species of Labeo in Kibos River is that of Labeo Victorians which belongs to the Cyprinidae. It is an andromous fish moving up rivers of the Lake Victoria and passing into floodwater pools to spawn. This migration occurs during the two rainy seasons in a year. (David 1981). In his work David has indicated that these fishes measure 20 cm to 30 cm in length (Greenwood 1966). Furthermore he has also indicated that of all fishes in the Lake Victoria this fish is very valuable in commercial sense. Despite their commercial importance, only a few studies have been carried out on this fish species (Olaf et al 1998).

Most Labeo Cylindricus length-at-(50%) maturity was attained at fork length of 96 mm for males and 98 mm for females, both within their first year of life. The rate of natural mortality was estimated to be extremely high at 1.93 years with maximum age of four years (Olaf L.F et al 1998).

Their migrations up rivers to spawn, makes them dependent on rainfall, river flow and other proximate environmental conditions (Olaf et al 1998). Thus, it is prudent to see and try to protect the hydrological regime of the river in terms of quality and quantity.

Description and Location of Labeo Fish(Ben 2009)

Description:	fish species living amongst rocks and in crevices in strongly flowing water
Flow Related Location:	strongly flowing water covering rocky bed and bedrock in main channels
Known Water needs:	require constant flow of water with little sediments to prevent suffocating by covering narrow opening or fissure, especially in a rock (crevices).

Links to Flow:

- The species live in crevices in the bedrock in flowing water conditions only and are reliant on these conditions. Any change in flow rate including lowering of water level, decrease in flow rate below normal ranges, increase in sediment load, change in water quality, including water temperature, dissolved oxygen and conductivity, will affect this group seriously.
- Breeding is associated with floods at the normal time. Some species undertake longitudinal migrations.

Habitat Requirement: Around rocks, feeding on aufwuchs (the small animals and plants that encrust hard substrates, such as rocks, in aquatic environments.)

2.5.3.2 Clarias (Large Fishes)

There are no studies on the Clarias gariepinus of Kibos River. However, there are few studies on this fish species of the nearby rivers such as Sondu-Miriu River which also drains into Lake Victoria like that of Kibos. Thus, the following are extracted from literature done on these rivers which will be used in conjunction with the result of the investigation. The review has also assisted interpreting and verification of information gathered from the site.

The African Catfish Clarias gariepinus (Burchell), has an intermittent occurrence in the Sondu-Miriu River draining into Lake Victoria (Henry 1991). In his study Henry has indicated that they are migratory fish between the lake and the river waters. Small sized and immature fish were available in the river throughout the year but their numbers become minimal in the dry season. Furthermore he has noted that fishing happens mainly during the high-water mark and rainy season of April-June and September-October, suggesting an upstream spawning migration. During these periods large size and mature fish occur in the river. This is because fish migrate from Lake Victoria and swamps into the river at this time. The movement could be associated with environmental changes brought about by rainfall and muddy conditions. In his study Henry also indicated that an upstream spawning migration occurring over short periods of time in Clarias of Lake Victoria have been reported (Greenwood, 1955, 1966; Cobert, 1960).

This species is endemic to the Lake Victoria drainage from where it was last recorded in 1997. It is thought that the species may have become extinct following intense predation by the Nile Perch (*Lates niloticus*), increased eutrophication of the lake, and possibly through overfishing. More surveys on a lake-wide scale are required to evaluate the "Possibly Extinct" status. (Snoeks et al 2006).

Description and Location of Clarias Fish (Ben 2009)

Description:	larger [>20 cm] fish species living in the channel
Flow Related Location:	stay in main channel and permanent pools during low water flow, migrating out to floodplain during floods. Migrate back to permanent waters as soon as flood water reaches a certain critical depth.
Known Water needs:	*As indicated for Flow Related locations above*

Links to Flow:

- Migration into floodplain takes place at different stages of flood. Timing of flood is thus very important to all these species as a late flood may depress successful spawning. A very early flood similarly affects spawning cycles negatively. This explains the absence of upstream migrations in the main channel of small fish during certain years when floods are small or out of phase (Ben 2009).
- The rate of filling of the floodplain may be very important for the stimulation of spawning of the different species.
- Feeding success depends on continued fertility of the floodplain, again depending on sediment deposition and maintenance of the floodplain vegetation and cycling of nutrients.
- Any disruption in the erosion and sedimentation in and onto the floodplain [including removal of certain particle size by trapping in dams], would have a serious cascading effect on this indicator.

Habitat Requirement: *As stated Flow for Related locations above*.

2.5.3.3 Barbus (Small Fishes)

There is little literature about Barbus altianalis, thus it is difficult to do a research (review) on the fish particularly on its life history. However, some papers have indicated that the spawning trend of this fish is similar to that of Labeo Fish. The paper published by Lake Victoria Basin Commission (LVBC, 2010) has explained how flood plains provide breeding and nursery habitats for migratory species such as Labeo, Barbus altianalis and Clarias gariepinus. The paper has also reported that these fishes are declining. Although fairly uncommon, the information obtained indicates Barbus paludiriosus has the potential to support important fisheries in small lakes and dams (Kalk et al. 1979). The species can reach 15 cm total length or more in favourable habitats; however Kenyan specimens caught so far have not reached 10 cm.

Description and Location of Barbus Fish(Ben 2009)

Flow Related Location: Flow Conditions same as clarias fish

Known Water needs:	Water need and other characteristics are almost the same as that of Clarias fish

Links to Flow: The same as that of clarias fish

Habitat Requirement:	Lives in marginal vegetation in the river but moves with first floodwater onto floodplain to colonise new deeper water bodies on floodplain. Breeds on floodplain, more than one generation per year.

2.6 Wetland Health

2.6.1 Classification of Wet land

There is distinction between wetlands and that of riparian and floodplain communities on the basis of standing water being the primary force determining plant assemblages in wetlands (Arthington et al 1998). Clarifying the distinction he stated that while flooding plays an important role in the ecology of riparian and floodplain plant communities, water drains off the land occupied by these communities soon after the recession of floodwaters. Wetlands can be considered as water storage systems, while riparian zones and floodplains act as conduits for water transmission.

In general the wet land can be categorized into two (Arthington et al 1998) :

- riverine floodplain wetlands, which are depressions within the floodplain that are fed by the adjacent river; and
- Terminal wetlands, which lie at the lowest point in a catchment and receive water that drains from the catchment. These can vary enormously in size depending on the area of catchment feeding them.

Nyamasaria swamp can be categorized under the second category.

2.6.2 Factors Affecting Wetland Health

Water is the key factor influencing the structure and floristic composition of vegetation communities in wetlands. Floristic composition and vegetation community structure in wetlands are determined by frequency, duration, depth and season of flooding. The assemblages of plant species in a wetland habitat are the result of a particular flooding regime occurring through time. Trees, shrubs and herbaceous plants respond to hydrological stress caused by either excess or insufficient moisture. In general, changes in water regime often result in changes to the floristic composition of a wetland (Chesterfield 1986; Bren 1992; Weiher &Keddy 1995; Casanova & Brock 1996; Nielsen & Chick 1997).

2.6.3 Wetland Hydrology

Regarding the wetland hydrology, in his work Arthington stated that virtually every structural and functional characteristic of a wetland is directly or indirectly determined by the hydrological regime (Gosselink & Turner 1978; Carter 1986; Gopal 1986; Mitsch & Gosselink 1986; Hammer 1992; Gilman 1994) which, in turn, is controlled by regional hydrological cycles and the landscape (Bedford & Preston 1988). Water regime is often considered the single most important ecological factor for wetlands (Breen 1990; Roberts 1990).

2.6.4 Wet land Eco-hydrological Relationship

The physical, chemical and biological functions which give wetlands their unique character and habitat value are driven by water availability (Gippel

1992). Both seasonal and year-to-year variations in rainfall and run-off produce natural cycles of water level fluctuation in wetlands. Changes in water level, flooding and low flow have beneficial effects on the productivity of wetlands

Water exchange between rivers and wet land areas has also been noted as a key component of wetland health. With frequent exchange, the water quality in the wetlands remains good (HEC-EFM 2009). The reduction of base flows need to be controlled otherwise, dissolved oxygen levels drop, wetland areas become anoxic and aquatic species die. The effect will be pronounced in warm and low flow months. For active exchange approximately 70% exceedance (30% of the time) in these periods will lead to healthy conditions.

2.7 Ecological Sustainable Water Management

The water needs of humans and natural ecosystems are commonly viewed as competing with each other. Certainly, there are limits to the amount of water that can be withdrawn from freshwater systems before their natural functioning and productivity, native species, and the services and products they provide become severely degraded. Water managers and political leaders are becoming increasingly cognizant of these limits as they are being confronted with endangered species or water quality regulations, and changing societal values concerning ecological protection. During the past decade, many examples have emerged from around the world demonstrating ways of meeting human needs for water while sustaining the necessary volume and timing of water flows to support affected freshwater ecosystems. It is an increasing belief that the compatible integration of human and natural ecosystem needs (identified here as ecologically sustainable water management) *should be presumed attainable until conclusively proven otherwise*. Richter (2003) offers this touchstone for such efforts as follows:

> ***"Ecologically sustainable water management protects the ecological integrity of affected ecosystems while meeting intergenerational human needs for water and sustaining the full array of other products and services provided by natural freshwater ecosystems. Ecological integrity is protected when the compositional and***

structural diversity and natural functioning of affected ecosystems is maintained."

2.8 Assessing Stream Health, Stream Classification and Environmental Flows

2.8.1 Criteria for Assigning Risk Levels

Once the flow regime is modified it is obvious to expect changes in the river environment (within and off-stream habitats). However, as described in the previous section it is possible to maintain the environment by allowing some specified flows downstream and this process is called e-flow prescription. Many different aspects of hydrologic variables can influence fresh water biota and ecosystem process, but in constructing ecosystem flow prescriptions river scientists generally focus on these key components of flow regimes: wet and dry-season base flows, normal high flows, extreme drought and flood conditions that do not occur every year; rates of flood rise and fall; and inter-annual variability in each of these elements (Arthington and Zalucki 1998). However, most often it is difficult to identify a single discharge value above which the habitat of all species can be maintained at/or near optimum. To accommodate these differences, Arthington et al. (1992a) recommended a band of flows rather than a single flow. The inflection point for changes in suitable habitat for 'food producing area' was also contained in this band of flow. Arthington et al. (1992a) reasoned that maintenance of food production was probably more important than minor deviations away from optimal habitat for individual species. Davies and Humphries (1995) also recognised this problem but dealt with it in a novel and more structured manner involving a final component of risk analysis (see Table 2-1 below).

Table 2-1: Criteria for assigning risk levels for different values of changes in habitat (ΔHA) relative to the reference flow (Q_{mp}) for key ecological variables Derived from Davies and Humphries (1995)

Risk category Variables	I No risk or beneficial	II Moderate Risk	III High Risk	IV Very High Risk*	V Degraded**
ΔHA for stream bed, mussels, invertebrate species-richness and abundance, trout and blackfish	>85%	60-85%	30-60%	30%-10%	<10%
ΔHA for macrophyte beds and snag piles	<25% sites with <75% wetted area cf Qmp	≥25% sites with <75% wetted area cf Qmp	≥50% sites with 75% wetted area & 25% sites with <50% wetted area cf Qmp	≥25% with 25% wetted area & cf Qmp	
ΔHA for individual invertebrate taxa	<10% of taxa with <75% WUA cf Qmp	≥10% of taxa with <75% WUA cf Qmp	≥25% of taxa with <75% WUA & ≥10% of taxa with <50% WUA cf Qmp	≥50% of taxa with <25% WUA cf Qmp	

* Modified to suite the objective of the thesis based on Tennant 1976, for fair or degrading flow category (Arthington et al 1998)

** Added to suite the objective of the thesis based on Tennant 1976, for severely degrading flow category (Arthington et al 1998)

Q_{mp} = the mean natural flow

From this table it can be seen that various levels of risk can be assigned to different flow levels on the basis of the amount of habitat loss that occurs for a proportion of all target taxa. The problem of maintenance of differing levels of habitat at the same discharge is a critical one. If the objective of an environmental flow assessment is to maintain species diversity, as was one of the objectives of Arthington et al. (1992a), then conceivably one flow may favour one species to the detriment of another.

For Kenya no such guidelines have been set; thus in the absence of such guide it is recommended to use proven band of flows to start with and modify the bands based on monitoring of eco-changes.

2.8.2 Criteria for Assigning Critical Flows

The other method, which has been mostly used worldwide, is that developed by Tennant in 1976 (Nancy et al 2004). This method is one of those categorized under hydrological methods of EFA. Hydrological methodologies use simple rules based on flow duration or mean discharge to scale down the natural flow regime. The Tennant method (Tennant, 1976) also referred to as the ‘Montana’ method, is the most commonly applied hydrological methodology worldwide (Tharme, 2003). Recommended minimum flows are based on percentages of the average annual flow (over the record, with different percentages for rainy and dry months).

The recommended levels are based on Tennant's observations of how stream width, depth and velocity varied with discharge on streams. The following table presents the recommended values by Tennant 1976.

Table 2-2 Critical minimum flows required for Fish, Wildlife and Recreation in streams identified by Tennant (1976)

Description of flows	% of annual flow	
	dry season	**wet season**
Flushing or maximum	200% of the mean annual flow	
Optimum range	60%–100% of the mean annual flow	
Outstanding	40	60
Excellent	30	50
Good	20	40
Fair or degrading	10	30
Poor or minimum	10	10
Severe degradation	0-10% of the mean annual flow	

In their work (Nancy et al 2004) have indicated the following findings and conclusions of Tennant theory:

- At 10% of the average flow (the mean daily flow, averaged over all years of record), fish were crowded into the deeper pools, riffles were too shallow for larger fish to pass, and water temperature could become a limiting factor.
- A flow of 30% of the average flow was found to maintain satisfactory widths, depths and velocities.

The method was designed for application to streams of all sizes, cold and warm water fish species, as well as for recreation, wildlife and other environmental resources.

3. DESCRIPTION OF THE STUDY AREA

3.1 Location

The study area is located from 0^{o}00' N and 34^{o}48' E to 0^{o}05' N and 34^{o}49' E within the Lake Victoria drainage basin on the high plateau of Nandi forest (***Figure 1-1 and Figure 3-1***). The elevation of the project area is in the range of 1940 m.a.m.s.l and 1960 m.a.m.s.l at the upstream end and 1135 m.a.m.s.l at the downstream end at Nyanza gulf. The River section starting from the dam site upto the existing water supply diversion is dominated by rapid and followed by the gently undulating plateau upto a point where Awach and Kibos confluence. Just a few kilometres off this junction the canalised section of the river starts. Then the river flows into Nyalenda swamp and finally drains into Lake Victoria.

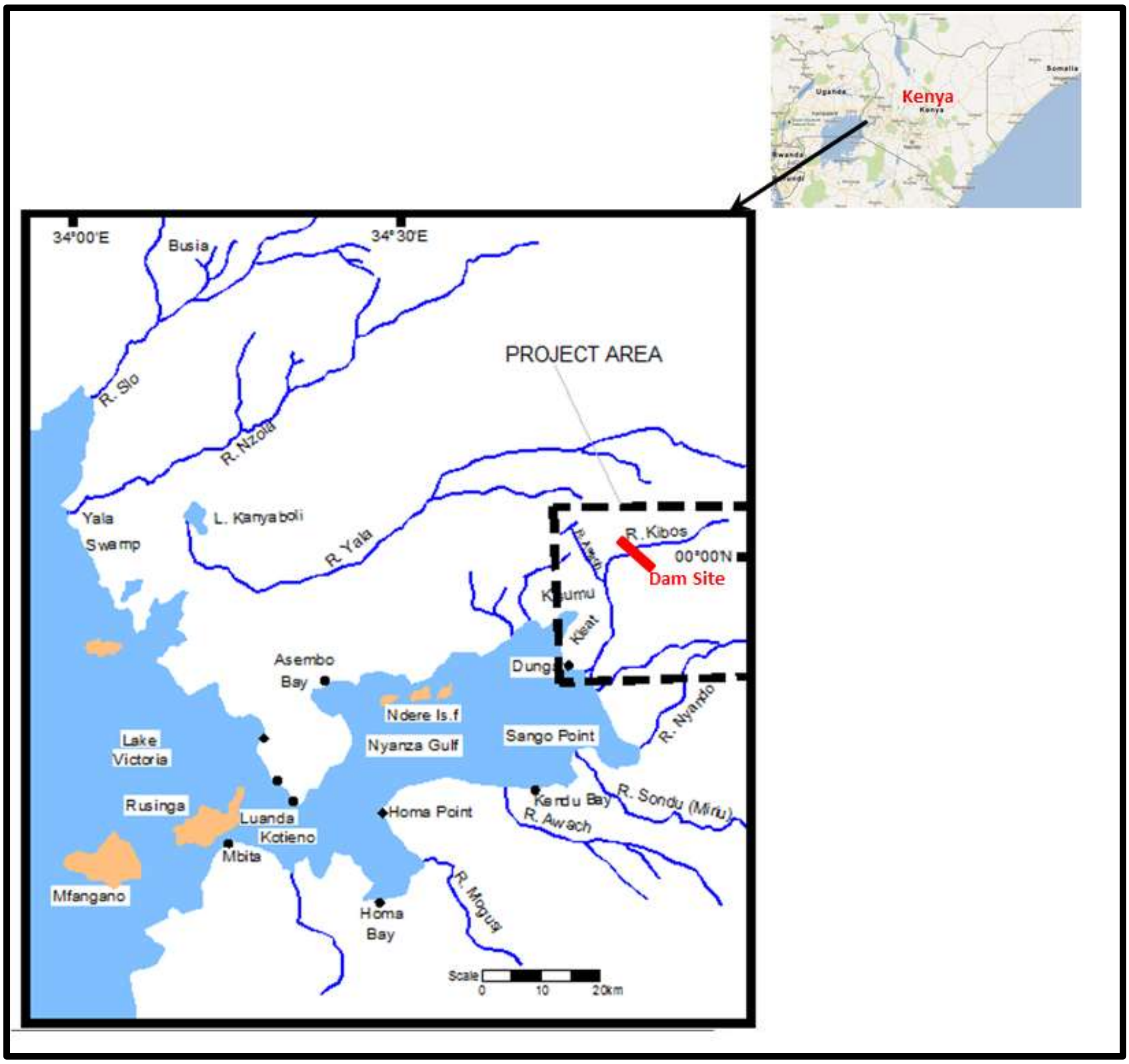


Figure 3-1: Project Location Map

3.2 Population

The 2008 Michel Parkman Study has projected the population of Kisumu and its surrounding areas. The then projection had estimated that the population of Kisumu is expected to reach 327,746 by 2011, 533,000 by 2025, and 622,618 by 2031.

Table 3.1: Projected Population of Kisumu (Source Michel Parkman's 2008 study)

Year	**2006**	**2011**	**2020**	**2031**
Population	327,746	372,627	469,463	622,618
Population to be served	291,518	331,436	417,569	553,793
Water Demand (m^3/day)	41,651	47,352	59,660	79,123
Average per capita consumption (l/p/day)	*142.9*	*142.9*	*142.9*	*142.9*

3.3 Temperature

The temperature variation in Kisumu is shown in ***Figure 3-3*** (Daniel 2010). The mean maximum and minimum temperatures occur in March and July respectively.

The evaporation does not vary much and almost equals the rainfall, except during the rainy seasons when the rainfall is higher than the evaporation.

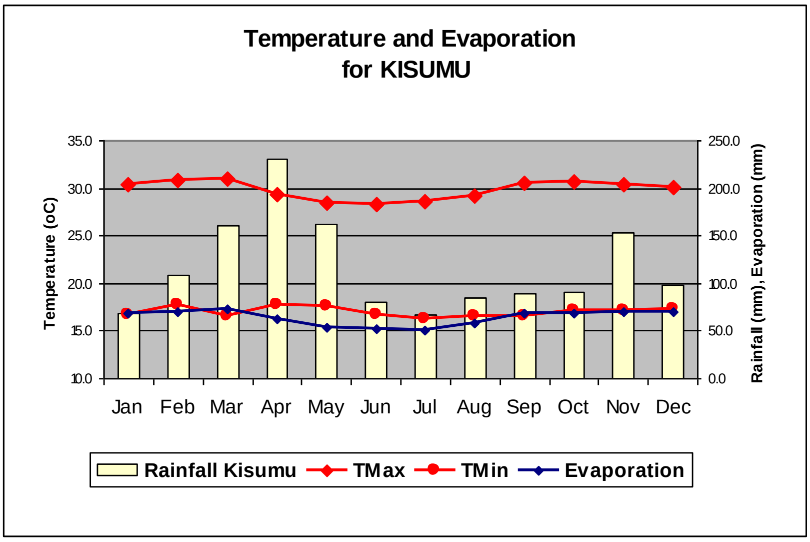


Figure 3-2: Mean Monthly, Maximum and Minimum Temperature and Mean Monthly Evaporation

3.4 Rainfall

Kisumu and its surrounding experience short wet season (March to May) while other areas such as Kericho receive rainfall for almost seven months. The mean annual rainfall, estimated based on 1980-1990 data, is 1,275 mm; the monthly distribution of rainfall at Kisumu Meteorological Station is shown in ***Figure 3-3***. The months of September, October, November and December occasionally experience heavy rainfall.

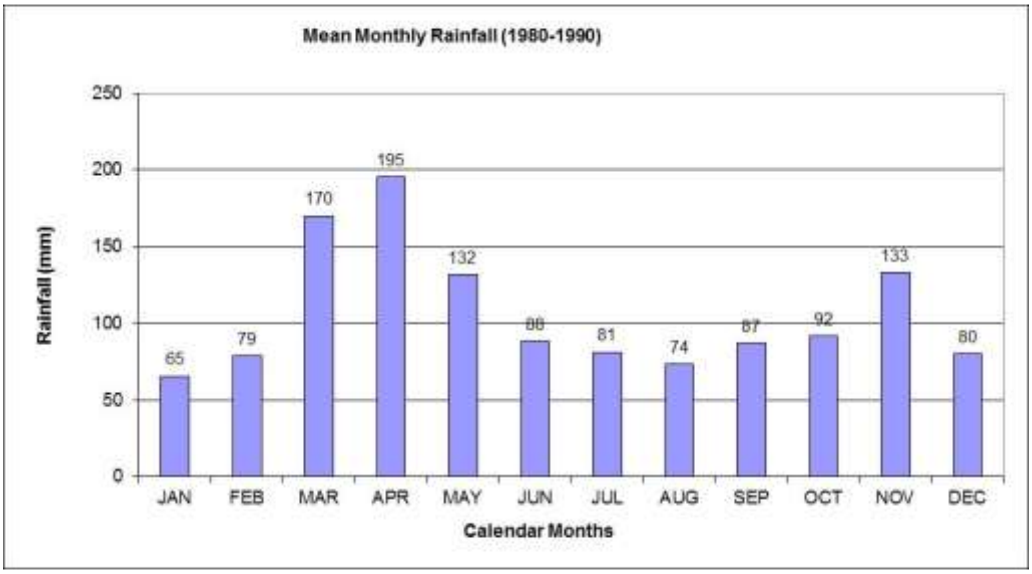


Figure 3-3: Mean Monthly Rainfall (1980-1990)-Kisumu Meteorological Station

3.5 Hydrology of Kibos River

The Michel Parkman 2008 study carried out a brief hydrological analysis for Kibos River. The result was presented as monthly values. No daily values were presented in the report. Daily values are needed for use for run-of-river scheme. The river has highest mean monthly flows during months of April, May and July and low flows during months of January, February and March. ***Figure 3-4*** present details of the monthly mean flow data established by the study.

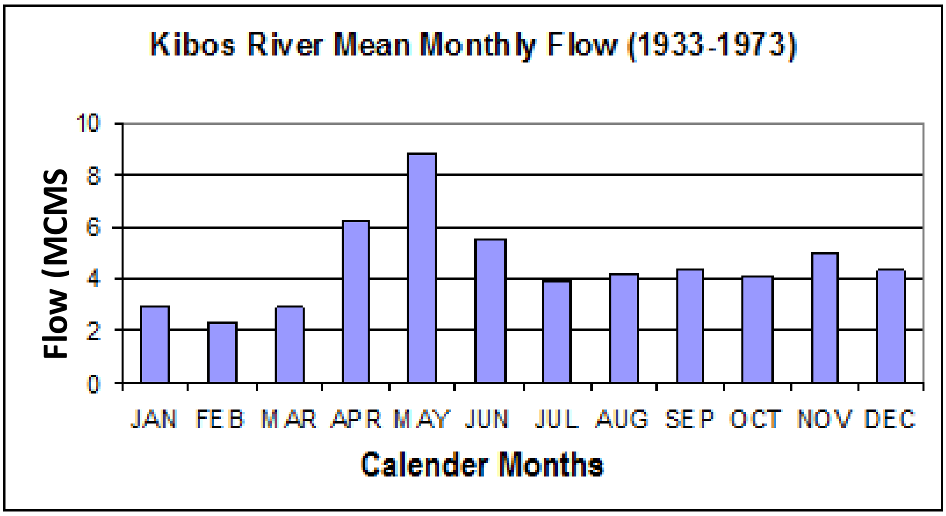


Figure 3-4: Mean Monthly Flow (1933-1973)

3.6 Kibos Yield and Water Demand Balance

The flow record at the proposed diversion intake from year 1932 to 1998 has been collected and plotted with possible flows to be diverted under different operating conditions. As shown in **Figure 3-5** the river will be left dry over several months in a year which will be impacting its ecology, thus, the need for assessment of environmental flows.

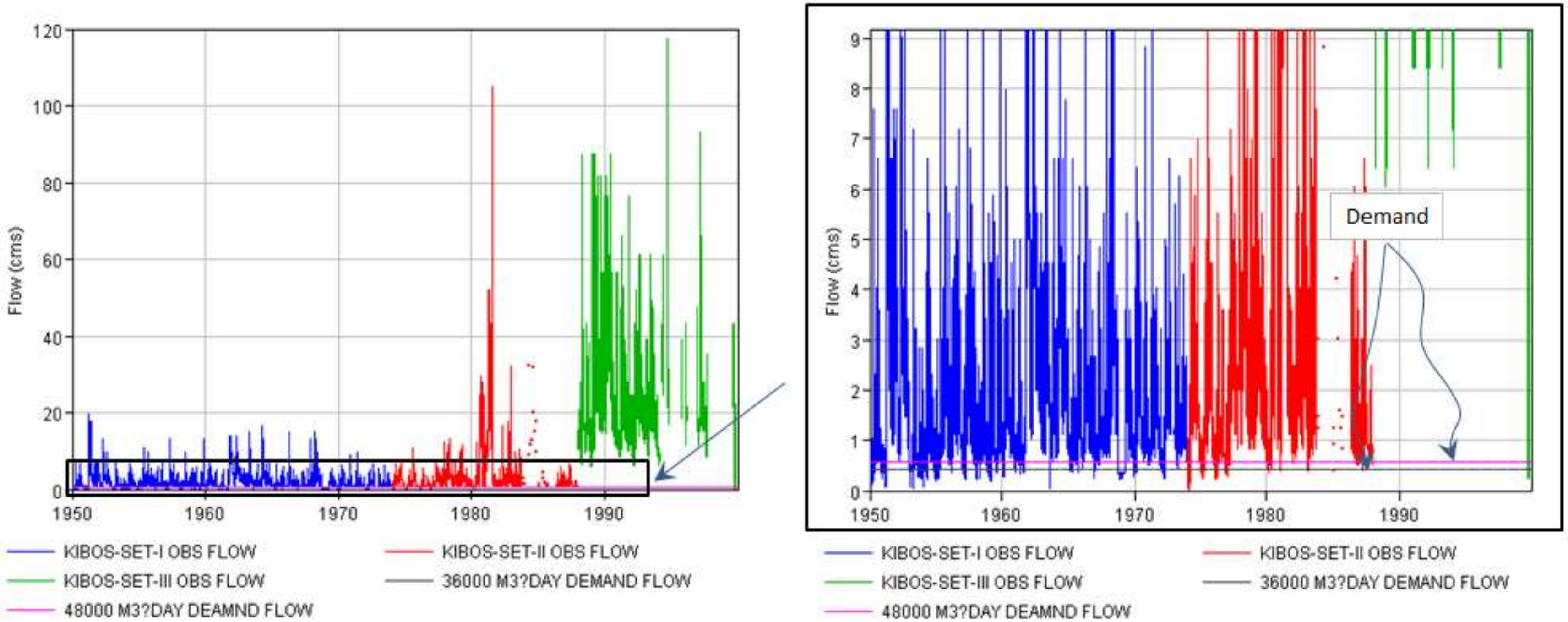


Figure 3-5: Average daily Flow Vs Demand.

3.7 Existing Facilities

The water supply and sanitation system for Kisumu consists of the following components. The relative location and capacity of the facilities are shown in ***Figure 3-6*** and details are presented in the following sections.

3.7.1 Water Supply Facilities

At present Kisumu town is being supplied from Lake Victoria. The facilities at the source consist of raw water pumping station, treatment plant and clear water pumps which pump the clear water to Kibuye and Watson reservoirs.

Due to population growth and standard of living the demand for the town is expected to grow in the future. As part of the long term plan Lake Victoria South has embarked on a water supply project on Kibos River in order to cover the medium and long term water demand of the town. The facilities included for implementation are the following:

1. 10 m high dam on Kibos River (future plan)
2. Diversion intake at Kajulu Water treatment Plant (Under Construction)
3. 48000 m^3/day Water Treatment Plant (under construction)
4. Kajulu, Mamboleo, Kibuye etc tanks (under construction)

Kisumu town at present is being supplied through two major service reservoirs namely Kibuye and Watson reservoir. In order to cater for the hourly demand variation and for other purposes the system is planned to be provided with additional service reservoirs which are under construction. These reservoirs include Kajulu Tank at Kajulu Water Treatment Plant, Mamboleo Tank which is located at Mamboleo Junction and Kayamheda Tank.

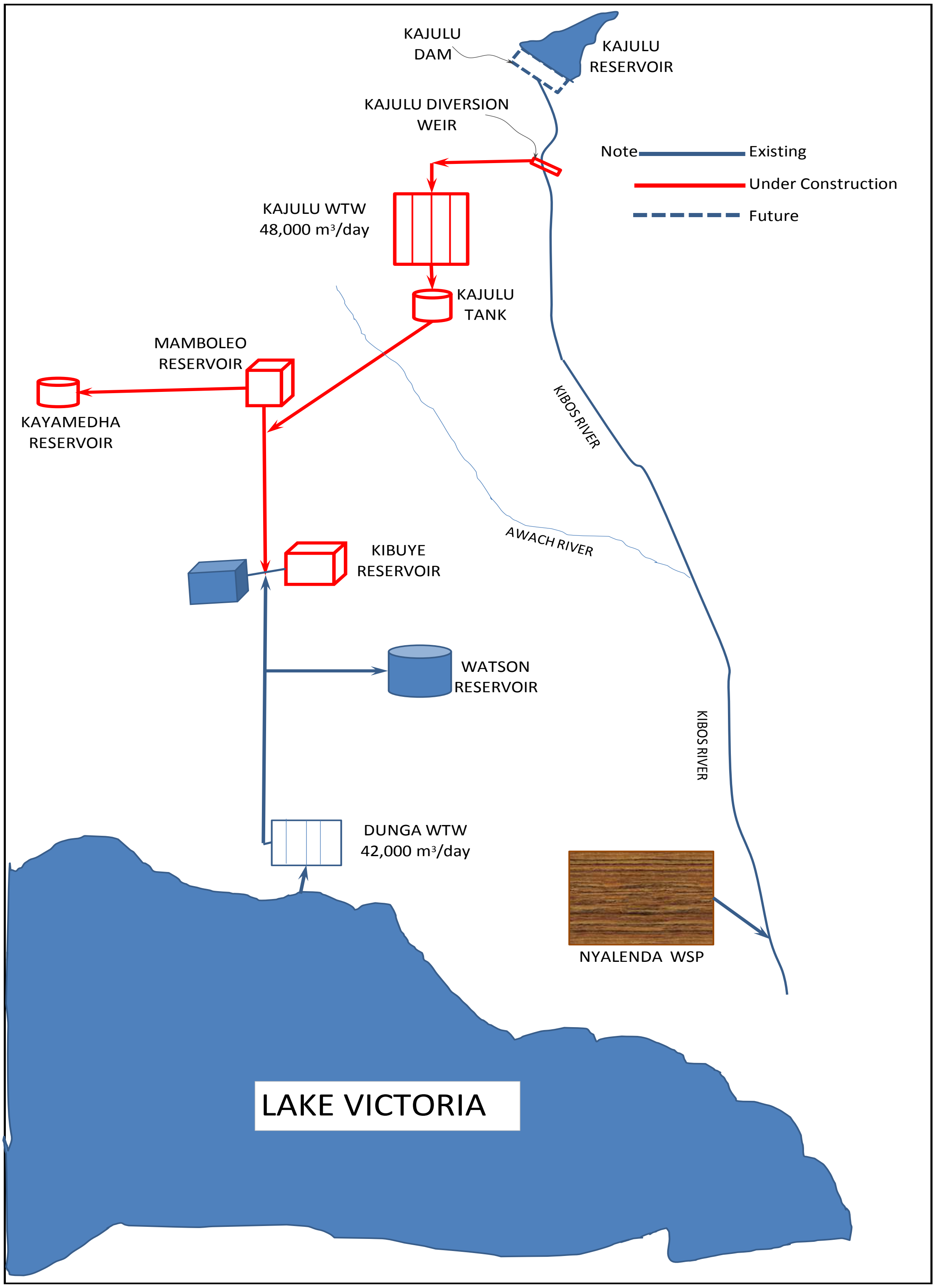


Figure 3-6 Existing Water Supply and Waste Water Treatment Facilities

3.7.2 Waste Water Treatment Facilities

The waste water from the town is being treated at two treatment facilities. The first is Kisat treatment facility which is a conventional waste water plant. The second facility which is one interests of this thesis is that of Nyalenda Waste Water Stabilization Ponds. The rehabilitated and expanded facilities of Nyalenda WSP are expected to treat domestic waste water upto 29000 m^3/day. The system is designed such that the effluent will be discharged into Kibos River. Schematic layout showing the above described facilities is presented in ***Figure 3-6***.

4. MATERIALS AND METHODS

4.1 Technical Approach and Model Development

4.1.1 General

The Ecosystem Functioning Model (EFM) is intended to predict how aquatic and terrestrial ecosystems along a river reach may be impacted by the implementation of water resources development projects (such as Kajulu Water Supply Project) which are expected to change the flow regime. The EFM can evaluate and compare existing conditions, with and without project conditions. Using input variables such as flow, existing vegetation, topography, and aquatic data, the model can evaluate how changes in flow regime and riverine morphology would impact key attributes of the river ecosystem (John et. al 2004).

In general, the EFM is a valuable planning tool in that it can anticipate biological consequences that may not be fully realized for many decades. Flow data and floodway characteristics for existing and with-project conditions are processed through the functional relationships of the EFM to produce basic indicators of biological changes.

The model is capable of simulating flow regimes for pre and post water resources development projects which can also be used for environmental restoration measures that change the flow regime or physical characteristics of the river channel. Changes to the flow regime could result from reservoir operation, new flood storage, changes to weirs, or other measures that affect the timing or magnitude of flood peaks.

4.1.2 Technical Approach

The EFM uses a set of identified functional relationships between river flow, floodway morphology, and the biological communities that inhabit the channels and floodplain lowlands. The technical approaches for this study have basically been adopted from the approach used by USBR in 2002 in the Sacramento and San Joaquin River Basins.

4.1.3 Model Development

The EFM is not a single computer model or program; rather, it is a process for evaluating biologic, hydrologic, and hydraulic variables that can be applied to multiple study areas and alternative conditions. ***Figure 4-1*** is a modified version of the five steps used during evaluation of Sacramento and San Joaquin River Basins EFA study by USBR in 2002. The steps used by the study were modified and applied in this thesis. This process diagram is included to show the processes and steps followed during the research.

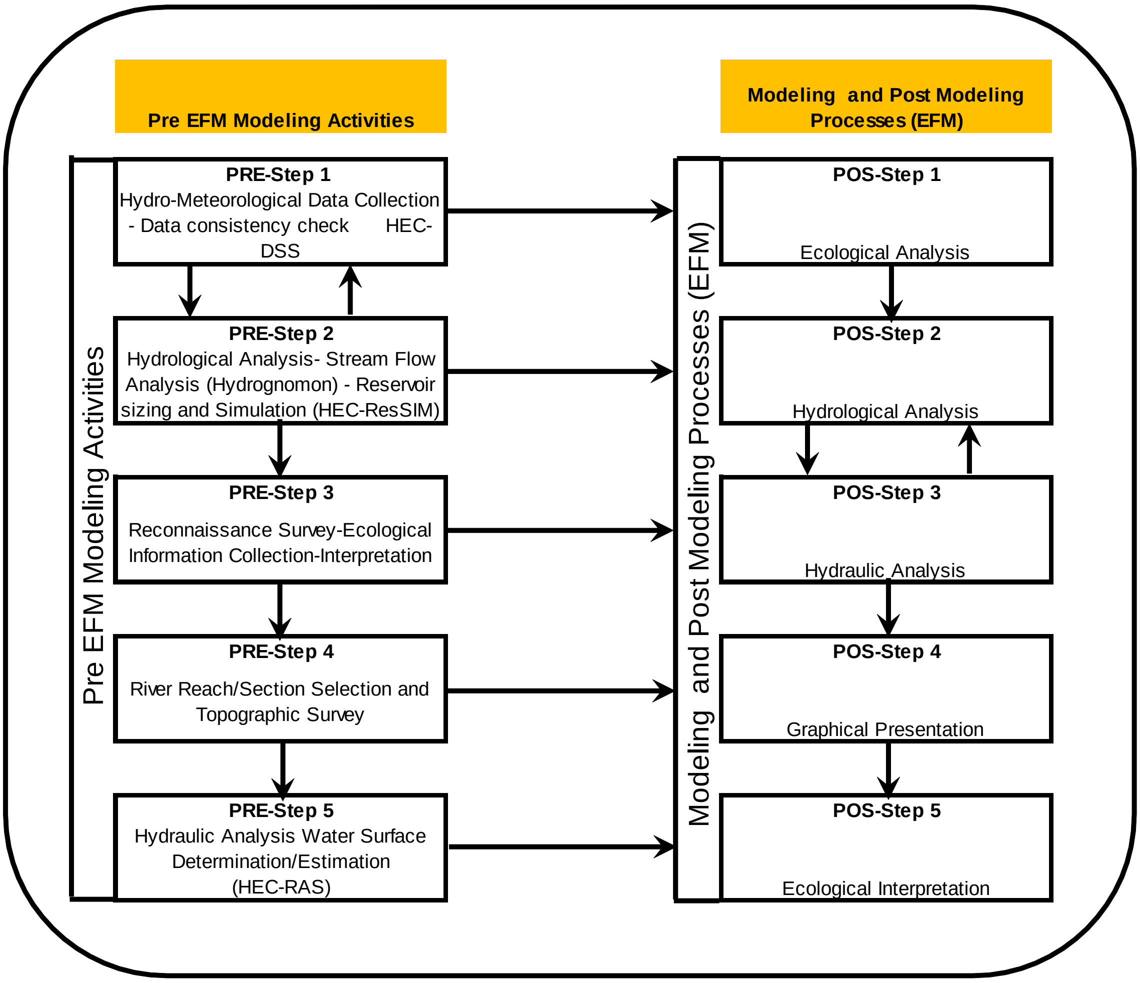


Figure 4-1 Technical Approach and Modelling Processes and Steps

4.2 Pre-modelling Activities, Processes and Steps

Data requirements of HEC-EFM are related to the level of details required by the modeller. The data which are mandatory for EFA are:

- Flow regime data to be analysed
- Eco-hydro relationships

These two sets of data will enable the researcher to carry out statistical analysis and obtain results. However, if the intentions are to carry out analysis and visualize results spatially as well, the following sets of data are required:

- Flow and stage time series
- Eco-hydro relationships
- Digital topographic data
- A geo-referenced hydraulic model
- And any other spatial data relevant to the ecosystem investigations such as land use, etc.

4.2.1 Hydrological Data Collection (PRE-Step-1)

This is one of the pre-modelling tasks carried out. At this stage, daily flow data for Kibos River and other nearby rivers have been collected from WRMA. A list of the daily flow records collected with other relevant information of the gauging stations and catchment commanded by the gauging station is presented in ***Table 4-1***. Kibos River daily flow data provided by WRMA has been checked by plot and compare method. As shown in ***Figure 4-2*** the flow record can be put into three groups, based on the base flow pattern and zero flows (low flow values).

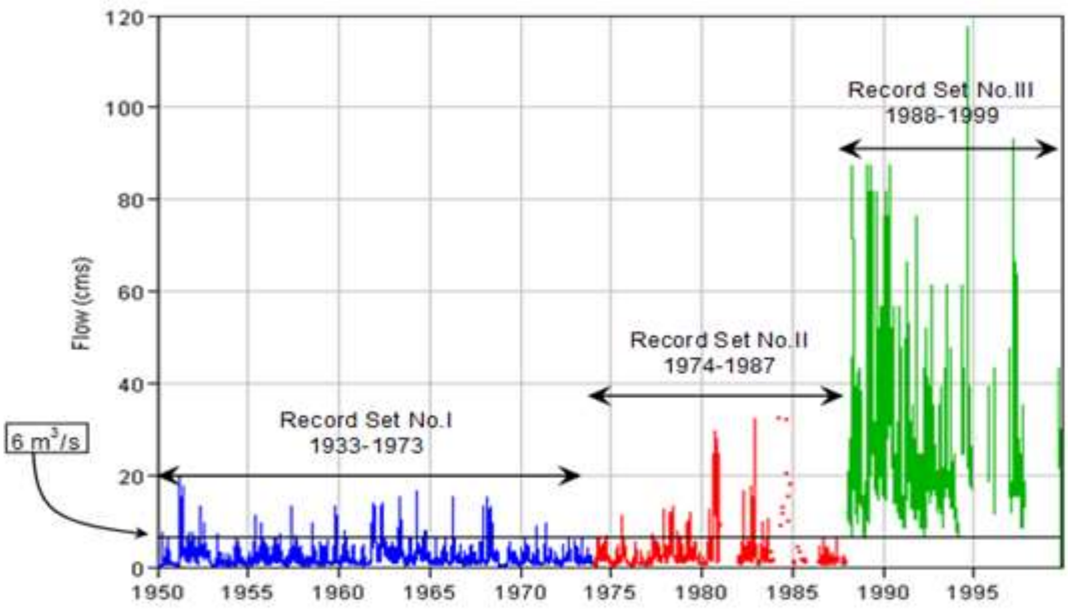


Figure 4-2: Mean Daily Flow Hydrograph (1950-1999) at Station 1HA04

The first group covers flow record from 1933 up to 1973; the second group covers flow record from year 1974 up to year 1987 while the third group covers flow recorded from 1988 up to year 1999. As shown there is high variability in the base flow and inconsistency in the data. This shows one of the following changes which might have occurred in the catchment area and/or gauging station:

- Catchment characteristics have changed to result in high base flow
- The control section at gauging station has changed due to sediment deposit.
- Some of the staff gauges have been moved to a relatively higher level/ground.

The last two phenomena could normally happen while installing and operating most gauging stations. However, when such changes occur, the rating curve should also have been changed to reflect the changes.

At this stage it will be difficult to derive new or modified rating curves for Kibos River as it will be beyond the scope of the research or the thesis. Thus, as most of the previous studies were based on flow data covering year 1933 to 1973, the thesis has considered the same data covering year 1933 upto 1973. This will give the same platform to compare the results of the thesis with these studies.

4.2.2 Hydrological Analysis (PRE Step-2)

4.2.2.1 General

Any environmental flow assessment reasons that if certain features of the natural flow regime can be identified and adequately incorporated into a modified flow regime, then the river environment and the functional integrity of the riverine ecosystem should be maintained. However the hydrological analysis carried out by the previous two studies were too brief to identify the critical features for consideration.

Since the two studies did not provide continuous, clear and consistent daily flow records there is a need to establish these data. Thus, hydrologic (flow) analysis and modelling have to be carried out. As a result these tasks have been considered to be critical and a substantial part of the investigation of environmental flow requirements for Kibos downstream of diversion intake.

The following sections are meant to discuss the methods used in the hydrologic analysis and modelling, and present the results from these studies. The hydrologic analysis and modelling involves:

1. Collecting and analysing the stream flow record. These include checking data record consistency, selection of record out of the available data and establishing operational hydrological parameters for the natural stream.

2. Establishing priority environmental flow objectives. These priority objectives were determined at the commencement of the hydrologic analysis and modelling, and are discussed in the subsequent section.

The Kibos flow record (1950-1973) collected from WRMA has 2.42% missing data. HEC-EFM does not allow using records with missing data. Thus missing data and gaps need to be infilled or extended. Additional data has been collected from the Hydrology Section of the WRMA for this purpose and to verify the result obtained from the flow-duration curve. Details of the gauging stations considered are shown in ***Table 4-1***:

Table 4-1: Details of Other nearby Gauging Station

Station Number	Station Name	Record Data			Latitude	Longtiude	Catchment Area km^2	Rated
		Start	End	No. Years				
RGS 1GB03	Chemosiet	1956	1967	12	00 35' 00"	35 03' 20"	1300	N
RGS 1GB05	Ainamouta	1950	1989	40	00 35' 05"	35 10' 30"	606	N
RGS 1GB06	Mbogo	1950	1989	40	00 36' 70"	34 08' 36"	67	
RGS 1GB06A	Mbogo	1973			00 36' 72"	35 08' 40"	67	
RGS 1GB07	Kapchure	1954	1967	14	00 60' 30"	35 06' 00"	129	N
RGS 1GB09	Ainamouta	1959	1967	9	00 36' 45"	35 04' 35"	743	N
RGS 1GB10	Kapchure	1959	1965	7	00 36' 70"	35 04'20"	158	N
RGS 1GB11	Ainopsiwa	1959	1996	38	00 38' 70"	35 10' 35"	142	N
1HA04	Kibos	1933	1974	42	00 60' 30"	34 48' 15"	117	Y
1HB05	Awach	1965			00 34' 80"	34 28' 25"	101	Y
Source : SMEC, Sondu-Miriu Hydropower Project Study					Infromation from JICA, 1992 Study			

Based on similarity of hydrological characteristics of Kibos catchment with the stations listed in the table, station 1BG05 has been selected for infilling and extension of the record from Kibos river flow gauging station. The criteria used for selection are:

- The catchment area ratio of the gauging stations to the station under consideration should be between 0.5 to 2. As show in Table 4.1 station 1BG05 cannot fulfil this criteria. However, the flows recorded at this station correlate better than others.
- The catchment slope
- Rainfall pattern
- Land use

Hydrological analysis has been performed using HEC-DSSvue and Hydrognomon. HEC-DSSVue is a Java-based visual utilities program that allows users to plot, tabulate, edit, and manipulate data in a HEC-DSS database file. It also allows performing operational hydrological analysis. Hydrognomon is a free software application for the analysis and processing of hydrological data, mainly in the form of time series.

4.2.2.2 Priority environmental flow objectives

The most widely used frameworks for environmental flows for rivers and streams are the twelve River Flow Objectives which are agreed to be the high-level goals for the management of flows for rivers, streams and other types of surface water (Arthington et al 1998). They identify the key elements of flow regimes that will both protect river health and provide the river environment needed for human uses such as recreation and aquaculture. Six of the twelve objectives have been identified as priority environmental flow objectives for the development of a new environmental flow rule for the Kibos River downstream of Kajulu Water Supply intake. These priorities are shown in ***Table 4-2***.

Table 4-2: Priority environmental flow objectives for prescribing a new environmental flow rule for Kibos River downstream of Kajulu Intake.

River Flow Objective	Aspects of river flow critical for protection or restoration of river health	Priority environmental flow objectives for the development of a new environmental flow rule
RFO1	Protect natural water levels in river pools and wetlands during periods of no flow.	Kibos has never dried. Thus, the Criteria/rule is not applicable
RFO2	Protect natural low flows.	Priority for environmental flow rule development.
RFO3	Protect or restore a portion of moderate and high flows.	Protecting a portion of moderate flows are a priority for environmental flow rule development. High flows will continue to occur as spill events. Especially for the run-off-river scheme this is not a problem
RFO4	Maintain wetland and floodplain inundation.	Will be considered as priority for the development of the Kibos Environmental flow rules. The Nyamasaria Swamp could be affected by the change of the flow regime but not during flood period.
RFO5	Mimic the natural frequency, duration and seasonal nature of drying periods in naturally temporary waterways.	The Kibos River is a permanent stream, and not a naturally temporary waterway.
RFO6	Maintain or mimic natural flow variability in all rivers.	Priority for environmental flow rule development.
RFO7	Maintain natural rates of change in water levels.	Objective will be achieved through rules set to achieve RFO 6.
RFO8	Manage groundwater for ecosystems.	N/A
RFO9	Minimise the impact of instream structures.	N/A
RFO10	Minimise effects of dams on water quality.	Need to be looked at to see the dilution effect of Kibos on effluent from Nyalenda Waste Stabilization Pond.
RFO11	Ensure that the management of river flows provides the necessary means to address contingent environmental and water quality events.	N/A
RFO12	Maintain or rehabilitate estuarine processes and habitats.	Priority for environmental flow rule development.

4.2.2.3 General Flow Patterns of Kibos River

Natural river flows are highly variable in space and time. During drought periods, natural river flows are typically low. However, during wet periods high flows (floods) can occur. ***Figure 4-2*** shows the historical flow variability of the total annual flows of Kibos River at station 1HA04. It can be seen that there are many years that are much lower or much higher than the average, showing how variable flows are in this river system. It also shows that the flows of Kibos River are dominated by low flows. Thus, the scheme which is under construction (run-off-river) would likely affect the flow regime.

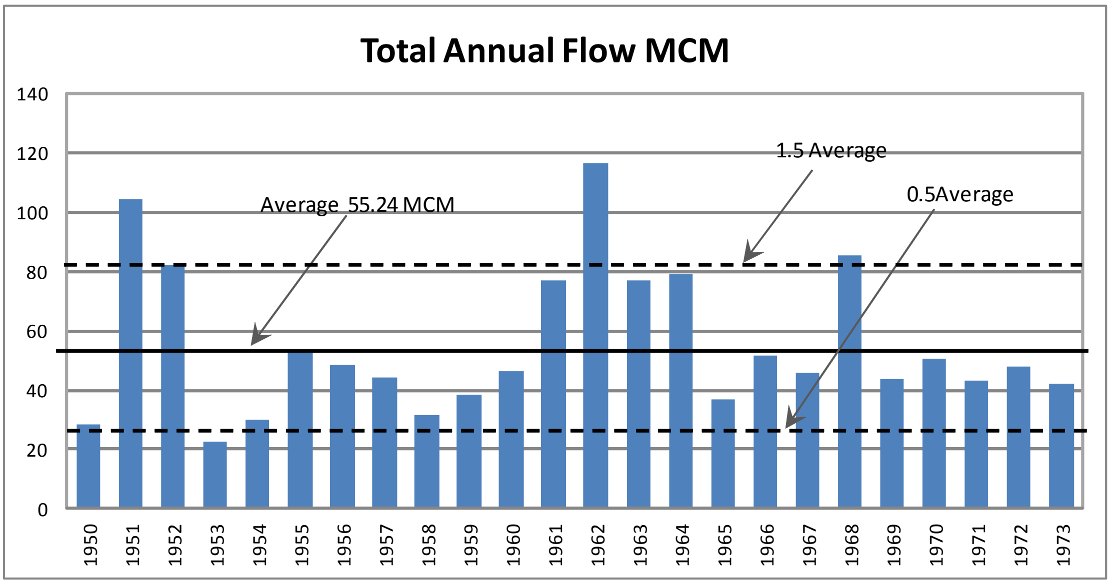


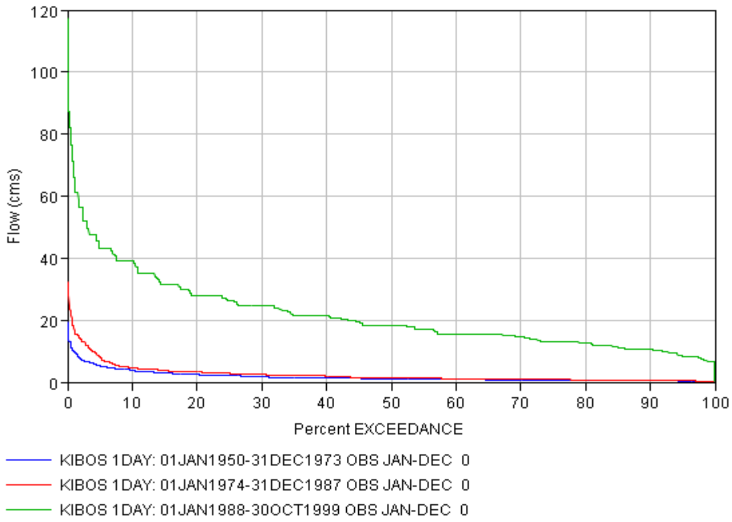
Figure 4-3 Total annual flows in Kibos River (at Station 1HA04) for the years 1950-1973

Understanding the way in which flows dynamically change in the Kibos River is essential for the development of an environmental flow arrangement that can meet the needs of the river. This involves examining the following 'aspects of flow':

- magnitude - volume of various flow events;
- duration - length of time for which the flow events occurs;
- seasonality - seasonal variation in flow events;
- variability - natural systems depend on variability in flow rates

4.2.2.4 Flow Duration Curves

The flow duration curve for the Kibos river at station 1HA04 has been established based on the daily flow data (5855 data points) over the period 1950 to 1973 (Figure 4-3). For the sake of comparison flow duration curves for data set II (1974-1987) and data set III (1988-1999) are also presented ***Figure 4-4***. The lowest flow record observed is 4752 m^3/day (55 l/s) in 5 April 1953. Tabulated values of the result of the daily flow duration analysis are presented in ***Figure 4-4***.



Exceedance Percent	Flow (m3/sec)		
	1950-1973	1974-1987	1988-1999
0.1	14.001	30.312	93.136
0.2	13.459	26.445	87.437
0.5	12.595	21.393	76.501
1	9.680	17.748	66.191
2	7.778	14.001	56.521
5	5.348	8.185	43.250
10	3.897	4.518	39.164
15	3.020	3.897	31.515
20	2.483	3.214	27.957
30	1.723	2.483	24.582
40	1.346	1.862	21.393
50	1.124	1.465	18.394
60	0.836	1.124	15.589
70	0.751	0.926	14.522
80	0.594	0.751	12.486
85	0.544	0.646	11.387
90	0.495	0.544	10.582
95	0.362	0.495	8.392
98	0.322	0.362	7.577
99	0.247	0.283	6.798
99.5	0.150	0.247	6.422
99.8	0.098	0.180	6.422
99.9	0.075	0.033	6.055

Figure 4-4: Mean Daily Flow Duration Curves (1950-1999)

Table 4-3 shows design flows considered by different studies. The table indicates that details on design flows (or flow duration curves) have not been provided by the studies. Thus, design flows computed under the current research have been considered to check the design capacity of the proposed water supply components (dam and raw water gravity main) or components which are under construction (downstream diversion weir, treatment plant etc). The flow that can be available 96% of the times is around 31,277m^3/day.

Table 4-3: Design Flows by Different Studies

Study	Flow (m3/sec)					
	Q_{25}	Q_{50}	Q_{75}	Q_{83}	Q_{90}	Q96
M. Parkman	--	--	--		--	0.451
Suereca						
Thesis	2.007	1.124	0.646	0.560	0.495	0.362

Study	Flow (m3/sec)					
	Q_{25}	Q_{50}	Q_{75}	Q_{83}	Q_{90}	Q96
M. Parkman	--	--	--		--	38,980
Suereca						
Thesis	173,405	97,114	55,814	48.384	42,768	31,277

From ***Figure 4-4***, the following can be concluded on the proposed water supply components (dam and raw water gravity main) or components which are under construction (downstream diversion weir, treatment plant etc).

"As per Kenya Design Manual, 2005 Section 4.2.1,
For Kajulu treatment plant having capacity above 31,000 m^3/day, storage must be provided even without considering EFR"

Table 4-4: Comparison of Design Capacity Vs River Flows

Treatment Plant Capacity (m^3/day)		**River flow Exceedance %**	**Scheme Type**
(m^3/day)	**(m^3/s)****		
24,000	0.278	98.574	Run-off-River
36,000	0.417	92.356	Storage Scheme
48,000*	0.556	83.579	Under Construction

* *Water Treatment Plant capacity under construction*

** *Equivalent river flow @ the corresponding per cent exceedance*

4.2.2.5 Sediment Transport and Design Consideration

Sediment is transported in rivers in suspension and as bed load. Sediment particles are kept in suspension by the turbulence of the river flow whereas bed load refers to sediment particles moving near the bed in a form of rolling or sliding. The suspended load consists of the wash load and the fine particles scoured from the bank of the river channel. The magnitude of the wash load depends on the current land use in the catchment.

Sediment load estimation consists of suspended load and bed load estimations. Its estimation is essential for the design of head works which consist of the intake works, and its ancillary works.

There is no systematic way of gathering data on suspended sediment at WRMA. Measurements are taken at random during low flow periods and high flow periods with the corresponding discharge. No measurement is taken on bed load as its measurement is very costly and time-consuming. Data on suspended load against flow helps to establish a sediment-rating curve. No such data was available to establish expression for sediment load transport for Kibos. In the absence of such data, regional values will be used to estimate the annual sediment yield of a river.

The total sediment volume estimated by the M. Parkman, (2008) study is 157,968 m^3, as per the report. This figure was arrived at by taking 20% of the live storage required (947,809m^3). The study did not give further information how the 20% figure is selected or arrived at.

Apart from the estimates made by M. Parkman, the sediment load can be estimated using regional values given by the Kenya Design Guide Section 7.1 as follows:

Table 4-5: Sediment Load Estimation

Erosion	Sediment Load $m^3/km^2/year$	Estimated for Kibos (m^3) 1year	15years	30 years
Low	500	62,500.00	703,125.00	937,500.00
Moderate	1000	125,000.00	1,406,250.00	1,875,000.00
Heavy	1500	187,500.00	2,109,375.00	2,812,500.00

It should be noted that the above load values have been estimated using compaction factor of 100%, 75% and 50 % for 1, 15 and 30 years respectively. As shown above, considering sediment load for moderately eroding catchment and catchment area of 125 km^2, the dead storage volume provided by M. Parkman study can be filled within 2 years even less. This shows that the dead storage provided by M. Parkman is very small and need to be revised. Thus for this thesis, the dead storage level has been revised. While revising the following assumptions have been made:

- The catchment area is dominated by moderately eroding surfaces
- The service life of the scheme is assumed to be 30 years
- It is assumed that the deposited sediment will be compacted by 50% over the service period.

Thus, as shown in ***Figure 4-5*** the dead storage level needs to be raised by 9.65 m (or moved up to 1484 m.a.m.s.l), from the originally proposed level.

This change will definitely affect the financial and technical viability of the dam and should be studied carefully prior to implementation.

4.2.2.6 Reservoir sizing and Simulation (HEC-ResSIM)

Why do we need to run simulation model

As shown in ***Table 4-4*** the capacity of the water supply scheme under construction is around 48000m^3/day, this flow is only available 84% of the time which is lower than the design discharge specified by the national design guide line, which states that, the design flow for surface water scheme should be available at least 96% of the time. Thus, unless it is planned to supply the town from other resources/sources or increase the water production capacity at Dunga, the system will be short in capacity. Accordingly, the previous study by M.Parkman (2008) has proposed to construct a small dam (referred as weir in the report).

This thesis has also evaluated the impact of the proposed dam on the environment (hydrological regime) if implemented. Thus, in order to investigate the implication of the dam construction the outflows from the dam need to be assessed. This has to be done through determination of reservoir capacity and set appropriate operation parameters (development of reservoir rule curves). It should also be noted that the main objective is to determine rcapacity which has to be sufficient to store water such that all downstream water needs can be satisfied. Thus, to determine optimum size of the reservoir, as per the required downstream water demand, the reservoir needs to be simulated, this was not done by the previous studies.

Table 4-6: Elevation-Area-Volume Data for Kajulu Reservoir (Source: M. Parkman)

Elevation (m.a.m.s.l)	Area (m^2)	ΔV (m3)	m^3	Elevation-Volume-Curve Equation Parameters a	b	Computed Elevation (m.a.m.s.l)
1471.00	-		-			1,471.00
1474.55	88,873	157,968	157,968	0.0000200000	1471	1,474.16
1475.00	100,000	200,000	200,000	0.0000200000	1471	1,475.00
1481.00	200,000	900,000	1,100,000	0.0000066667	1473.667	1,481.00
1481.50	212,500	103,125	1,203,125	0.0000048485	1475.667	1,481.50
1482.00	225,000	212,500	1,312,500	0.0000047059	1475.824	1,482.00
1482.50	237,500	328,125	1,428,125	0.0000040000	1476.788	1,482.50
1483.00	250,000	121,875	1,550,000	0.0000040000	1476.8	1,483.00
1483.50	262,500	128,125	1,678,125	0.0000040000	1476.788	1,483.50
1484.00	275,000	262,500	1,812,500	0.0000028571	1478.821	1,484.00
1484.50	287,500	275,000	1,953,125	0.0000022222	1480.16	1,484.50
1485.00	300,000	1,000,000	2,100,000	0.0000040000	1476.6	1,485.00
1487.50	350,000	1,687,500	2,890,625	0.0000035556	1477.222	1,487.50
1490.00	400,000	1,750,000	3,850,000	0.0000028571	1479	1,490.00
1494.00	500,000	1,800,000	5,650,000	0.0000022222	1481.444	1,494.00

For ease of reference and selecting reservoir operation levels the elevation volume curve is presented in ***Figure 4-5***:

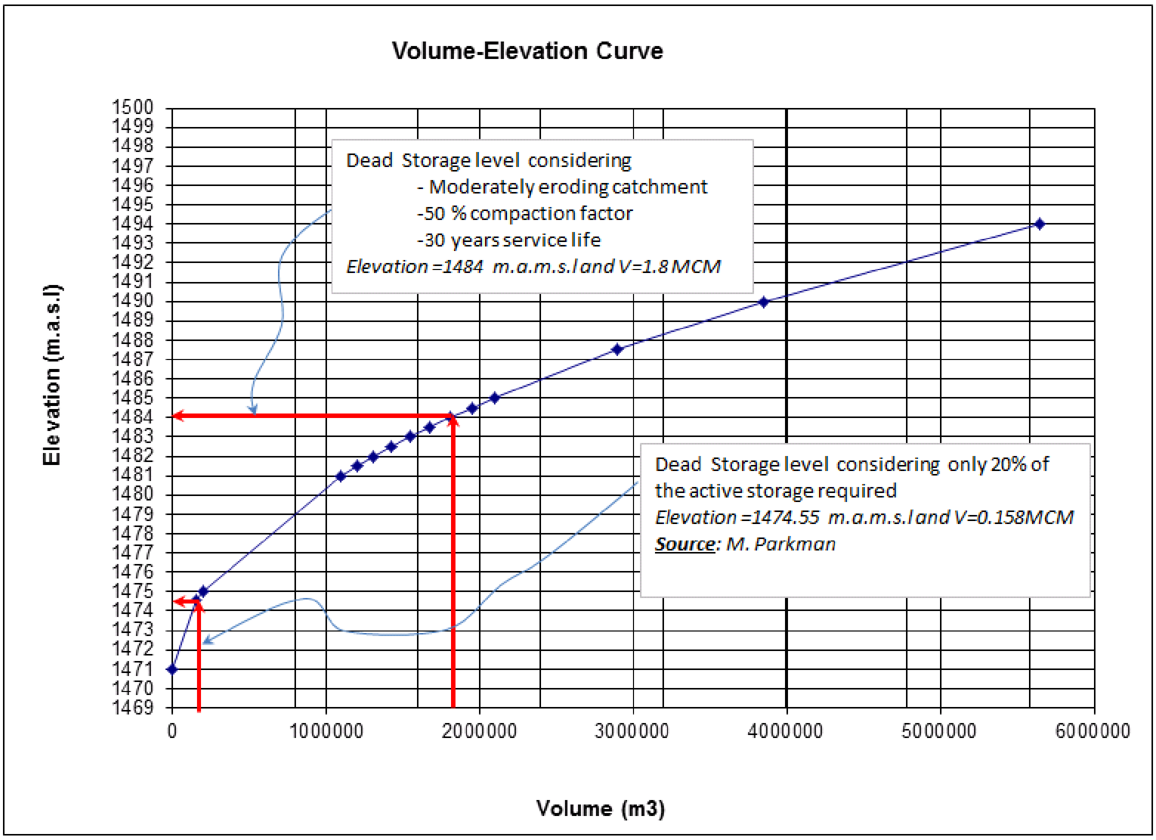


Figure 4-5: Reservoir Elevation-Volume Curve

Capacity Elevation-Area-Volume Curve

The elevation capacity curve has been extracted from M. Parkman Study and the extracted data presented in ***Table 4-6***:

Reservoir Rule Curves

Having revised the design flows and reservoir parameters as described in the previous sections and elsewhere in this thesis, it is believed that the reservoir needs to be simulated such that the required active (live) storage capacity is revised as well, which in turn will help to determine the total storage capacities and the overflow crest level. While determining the reservoir parameters it has been attempted to come up with best reservoir rule curve such that the out flows can meet all demands as much as possible. The simulation has been carried out using HEC-ResSim 3.0a. Details of the results of simulation are presented in Chapter 5.

4.2.3 Field Investigation/Survey (PRE Step-3)

Standard data collection forms or/and questionnaires for collection of primary and secondary data such as formats approved and used by World Bank for Environmental Assessment, did not exist. Thus, a modified questionnaire (Sacramento and San Joaquin River) has be prepared and used while collecting ecological information from different reaches/sections of the river. Sample data collection format (questionnaire) is presented in ***Appendix A1***. The questionnaire has been prepared based on questionnaire used for collection and analysis of Input Requirements for Terrestrial and Aquatic Relationships for Sacramento and San Joaquin River Basins Ecological Functioning Model USBR, 2002. Details of Ecological Field data collected at each River Section have been presented in ***Appendix A2 through Appendix A8***.

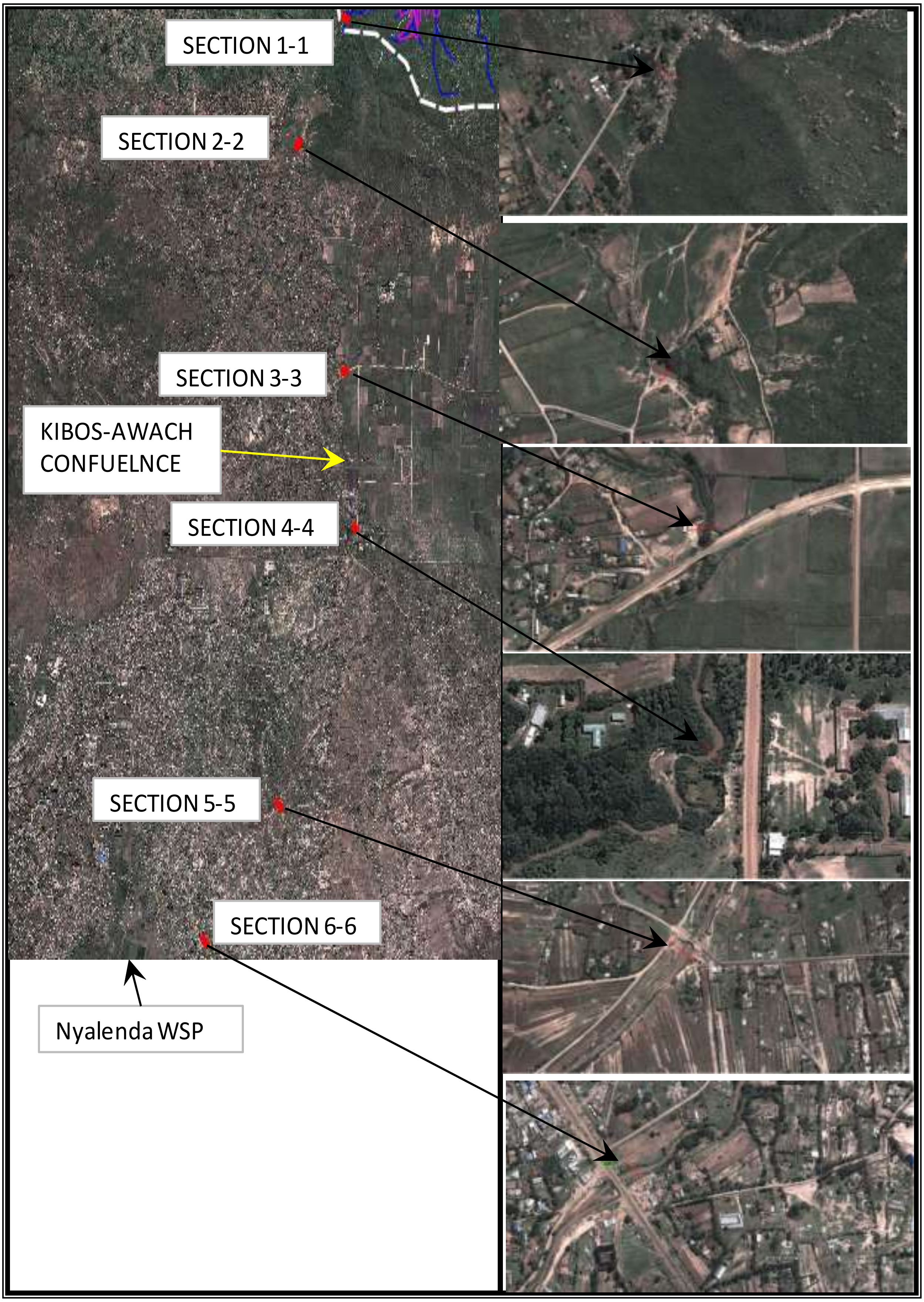


Figure 4-6: Selected River Reach/Section for Modelling/Analysis

4.2.4 River Reach Section Selection and Topographic Survey (RE Step-4)

Study sites for assessing the relationship between habitat availability of key species and water discharge are selected according to the protocol of Bovee (1982). Six river sections are identified within the Kibos River. All relevant data for each site (river morphology and ecological data) have been collected at these sections.

As shown in ***Figure 4-6*** the river can be divided into the following three river reaches:

- The first River Reach is the river section upstream of Kajulu Water Supply Diversion intake. This section will not be affected directly by the project thus not investigated in detail.
- The second River Reach is part of Kibos River between Kajulu Water Supply Diversion intake and confluence of Kibos and Awach River. This reach includes section 1-1, 2-2 and 3-3. This river reach can be represented by RIVER SECTION 1-1. This section covers 8.1km length of Kibos River.
- The third River Reach is down stream of confluence of Kibos and Awach River. This reach includes section 4-4, 5-5 and 6-6. This river reach can be represented by RIVER SECTION 6-6.

Of the six sites assessed, river section downstream of Kajulu Water Supply Diversion intake (RIVER SECTION 1-1) and section upstream of Nyamasaria Bridge (RIVER SECTION 6-6) were chosen as representative sections for ecological model analysis and interpretation (see ***Figure 4-6***). The top reach Kibos River (upstream of Kajulu Intake/dam) has not been surveyed as the project is not expected to affect it (only from hydrological point), however will require investigation, if water development project in the upper catchment occurs in the future.

4.3 Modelling Processes

4.3.1 Ecological Analysis (POS Step-1)

The ecological analysis identifies functional relationships between river hydrologic and hydraulic conditions and the riverine ecosystem/geomorphic system. These relationships reflect flow requirements for different habitat in terms of stream flow durations, return periods, and stage recession rates. The biological effects of reduction on flows are the subject of the ecological relationships for this thesis. Thus, the ecological analysis focuses on aquatic ecosystem rather than the usually two major elements: the terrestrial ecosystem and the aquatic ecosystem which will be affected due to major dam developments for big water resources development projects such as flood protection or hydropower development. The ecological analysis also has considered wetland ecosystem.

4.3.1.1 Aquatic Elements

The aquatic element focuses on the seasonal low flow to evaluate potential impacts and benefits to three representative native fishes, Labeo, Clarias and Barbus. This element incorporates criteria for suitable flows to benefit floodplain spawning, rearing, foraging/migration, and avoidance of stranding, and predicts spatial changes in the extent of suitable floodplain habitat. For ease of analysis the fishes in Kibos have been divided into two groups: large size fishes or sexually matured fishes and small size fishes or newly spawned fishes. The small sized fish group includes Labeo and Barbus. That of large sized fishes group includes Clarias. The eco-relationship for these two groups is presented in the subsequent sections.

4.3.1.2 Wet land

The wet land focuses on Nyalenda Wetland. Wetland will be affected by changing flow regimes from upstream rivers and the effect will be more pronounced if the low flow is significantly reduced. The reduction in flow might lead to lowering of the water table as well as reducing the diluting effect of the effluent from Nyalenda waste stabilization ponds. However impacts on biological habitat or impacts on individual habitat in and around the wet land were not investigated in detail. (Location of Nyamasaria Swamp in relation to Nyalenda WSP and Kibos River is shown in ***Figure 4-7***).

Figure 4-7: Location of Nymasera Swamp - Nyalenda WSP -Kibos River).

4.3.1.3 Aquatic Ecosystem

The aquatic ecosystem element consists of the following two parts:

- In-channel habitats
- Seasonal floodplain habitats

The first is the subject of this research and includes relationships that reflect the dependence of suitable channel characteristics at particular reach and section of the river such as substrate, instream cover, and bank vegetation on changes in flow regime and channel morphology etc.

The latter will not be impacted as appropriate operating measures are considered including using reservoir operating rule curves which can maintain flood flow regimes. This floodplain component incorporates conditions for suitable overbank flows that benefit floodplain spawning, rearing, and avoidance of stranding, used to predict spatial changes in the extent of suitable floodplain habitat.

4.3.2 Building Eco-Hydro Relation Ship

4.3.2.1 Spawning and Small Sized Fishes

Normally these types of fishes spawn in shallow (no deeper than 30 cm) vegetated, floodplain areas between Mid-April and Mid-July. Eggs require sustained high flows for approximately 21 days before hatching. These fishes reach sexual maturity in their first (most of the time) and second year and have a lifespan of approximately 4 years. Most literature suggest using the conditions within spawning seasons that generate the largest extent of effective spawning habitat as an indicator of success for each year's spawn. Further, literature suggests that good spawning conditions do not need to occur every year-it would be sufficient if there were good conditions in 25% of years, so that, on average, each of these fishes would have a chance to spawn in their lifespan.

HEC-EFM Relationship Small Size Fishes:

- *Season: Mid April to Mid July*
- *Duration: 21 days, minimums (sustained highs) and then Maximum (largest extent)*
- *Rate of change : Not applied*
- *Percent exceedance: 25% (4 yr) – flow frequency*
- *Hypothesis tracking : Increased flow will improve (+) floodplain spawning*
- *Geographical queries: Depth (0 to 0.3m) and vegetation (aquatic plants)*

4.3.2.2 Rearing and Big Size Fishes

Most literature on this group of fishes show that mortality is very critical over dry period. For the fishes in Kibos, the dry period is very critical, as the habitat condition deteriorates and the depth of the water reduces to the very few centimetres. These chronic conditions are best represented by average low flows and that, since these fish are in the river each year, using a typical year (median conditions) would be a good indicator. Studies show that suitable habitat is proportional to increasing low flows (i.e, higher low flows create suitable habitat) until those low flows exceed 1.142 m^3/s, which is 50%

exceeded flow). For Kibos this period covering January and February are critical.

HEC-EFM Relationship Rearing (Big Size Fishes):

- *Season: Jan to Feb*
- *Duration: 14 days, Means (average) and then Minimum (low)*
- *Rate of change : Not applied*
- *Percent exceedance: 25% (4 yr) – flow frequency*
- *Hypothesis tracking : Curve with flow-value points of 0-0, 0.2-5, 1.124-10, 3.00-0*
- *Geographical queries: Not applied*

4.3.2.3 Micro Invertebrate Biodiversity

Run-off-river schemes reduce low flows but have no significant impact on the high flows, which might create a more stable dry flow regime. In these dry periods communities of macro invertebrates often have reduced biodiversity because the few species that thrive in the more stable low to dry flow conditions out compete all of the others. Flooding initiates a return to more natural conditions which encourages the community to rebound to its original biodiversity. The time is not important, but the high flows should occur every two years, on average.

HEC-EFM Relationship Micro Invertebrate Biodiversity:

- *Season: April to May*
- *Duration: 1 days, Means (average) and then Maximum (high)*
- *Rate of change : Not applied*
- *Percent exceedance: 50% (2 yr) – flow frequency*
- *Hypothesis tracking : Increased flow will improve (+) biodiversity*
- *Geographical queries: Not applied*

4.3.2.4 Wetland Ecosystem

Water exchange between Awach and Kibos rivers and wetlands (Nyamasaria Swamp) areas has also been noted as a key component of wetland health. With frequent exchange, the water quality in the wetlands remains good. This is being especially witnessed for dilution of effluent from Nyalenda Waste Water Stabilization Pond. The reduction of base flows from the two or one of the two rivers need to be controlled otherwise, dissolved oxygen levels will drop, leading to the wetland areas becoming anoxic and aquatic species to die. The effect will be pronounced in warm and low flow months, September to December. For active exchange approximately 70% exceedance (30% of the time), i.e (0.375 to 0.75 m^3/s) in these periods will lead to healthy conditions.

HEC-EFM Relationship Wetland Ecosystem:

- *Season: March to April and September to December (Jan-March is selected for analysis)*
- *Duration: 1 days*
- *Rate of change : Not applied*
- *Percent exceedance: 15% (of time) – flow duration*
- *Hypothesis tracking : Increased flow will improve (+) water exchange for wetland health*
- *Geographical queries: Not applied*

Comment: The exchange is not only from Kibos to the wetland but also from Awach. Thus, if half of the flow of 30% (0.375m^3/s) is secured from Kibos and the remaining half from Awach, then health of the ecosystem is assumed to be protected.

4.3.3 Hydrological Analysis (POS Step-2)

This analysis has considered the parameters developed during pre-modelling process and that of the ecosystem relationships developed in Step 1 into discharges with specified durations, return periods, seasonal periods, and stage recession rates.

The statistical analysis uses pre project natural flow, historical flow, diversion scheme and revised dam and storage parameters (this includes changing the dead storage level and considering 48000 m^3/day system water production capacities). The analysis is conducted using HEC-EFM. As approaches, findings and recommendation of this step are the subject and objective of this thesis; details of the steps have been presented in Chapter 5.

4.3.4 Hydraulic Analysis (POS Step-3)

The hydrological analysis in step 2 above has been repeated for different reaches/sections of river Kibos. The statistically determined discharges from gauging stations are transferred to these selected river reaches/ sections using transposition during pre-modelling activities.

4.3.5 Graphical Presentation (POS Step-4)

The geographic analysis step involves the use of a geographic information system (GIS), such as QGIS, to geographically overlay hydraulic results (computed during pre-modelling activities, in step 2 and 3) with other ecological and environmental information. Data used in the geographic analysis includes digital terrain maps and satellite images. GIS provides a platform to display and compare results, allowing the planners to evaluate the pre and post project ecological transformation graphically and helps to propose ecosystem management and mitigation measures at different locations. Due to lack of digital elevation model at smaller contour interval this step 4 has been skipped.

However, the results of the field investigation, hydrological analysis and model output have been presented graphically using QGIS.

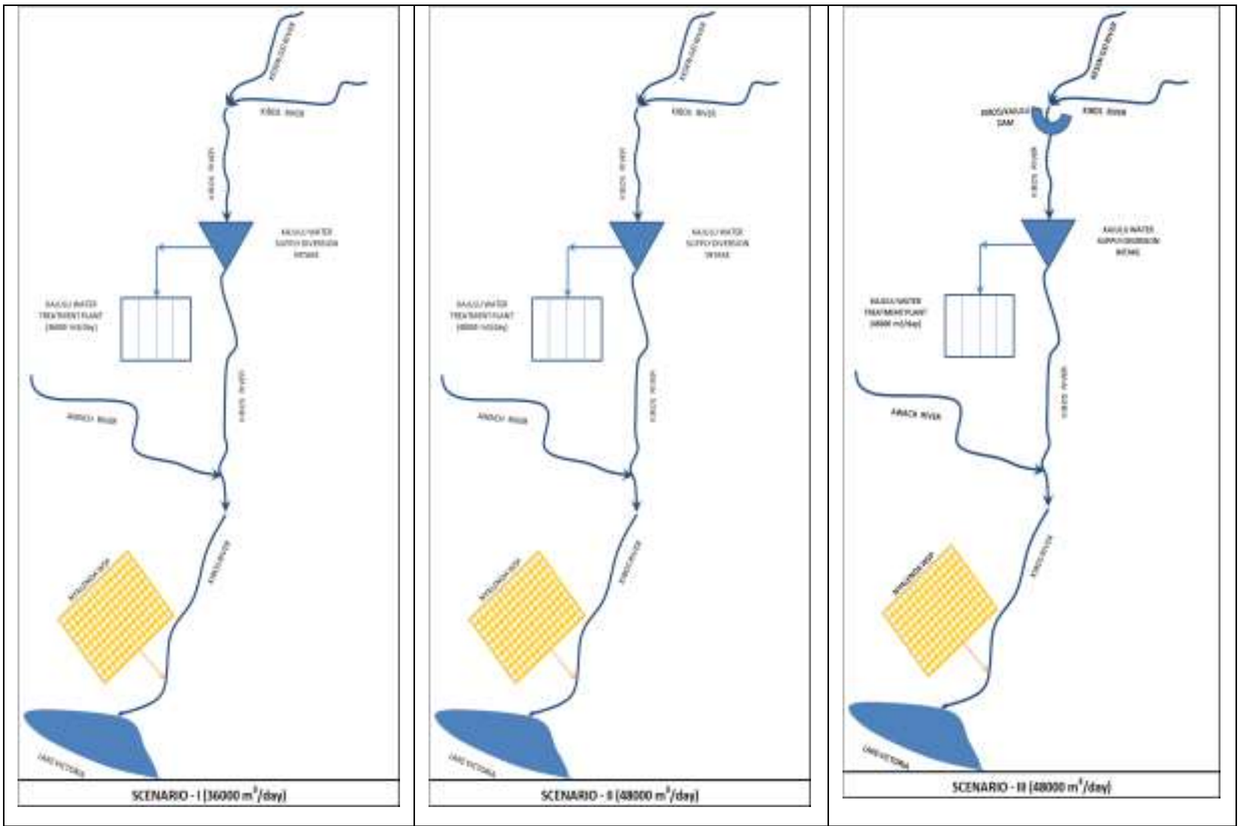
4.3.6 Ecological Interpretation (POS Step-5)

The final step in the EFM is the interpretation of results. The interpretation has been carried out based on the index calculated by the model and checking the flows, which is based on the modified Davis & Humphries and Tannent method, recommend percentage flows for determining minimum critical flows for fishes, wildlife etc.

4.4 Model Run Options

As described in Section 2, the decision to implement the current project has been based on the assumption that the upstream storage dam on Kibos will be implemented in order to supply water to Kisumu town at full treatment capacity. However, at present a run-off-river scheme with treatment plant having capacity of 48,000m^3/day is being constructed. Thus, it is in order to see the impact of the project with different components to come into the project through time. This will make the system to be operated at different flows. All possible operation options have been assessed. These options are:

- Scenario -I 36000 m^3/day Run-off-River
- Scenario -II 48000 m^3/day Run-off-River
- Scenario -III 48000 m^3/day (Storage Scheme)



Scenario-I (36000 m^3/day) (Run-off-River)	Scenario-II (48000 m^3/day) (Run-off-River)	Scenario-III (48000 m^3/day) (with Dam)

Figure 4-8: Project Scenarios

4.5 Risk Analysis

A risk analysis was performed to provide the following:

- a series of options for future water management plans; and
- the ecological risk of failure in not achieving these flows for each of these values.

This was achieved by determining the flow at which the useable habitat available to a species changes by a certain percentage, relative to that available if water supply diversion (off-takes) did not occur. The percentage changes in habitat that determine risk categories were taken from Davies and Humphries (1996). This analysis was performed for each of the key biota (fish and other species).

The risk analysis used in this study is a modification of that developed by Davies and Humphries (1996). Risk is based on changes in habitat (ΔWUA) relative to a reference flow. In this study the reference flows used were the median monthly flows at each site for the period 1950 to 1973 adjusted to account for diversion for water supply under different operating scenarios (i.e. the median monthly flows at each site that would have occurred without abstraction).

In this case there are 3 risk categories, and four variables (see Table 2-1). The variables include:

a) adult of Clarias, barbus and labeo fishes which are believed to indicate habitat for rearing

b) early young of (0 to 1 year) these fishes, which are believed to indicate/evaluate the spawning and sexual maturities

c) Micro combined invertebrate (believed to protect species such as the snail and others)

d) Wetland (Nyamasaria swamp)

As shown above the method uses WUA (Weighted usable area) for Q_{mp} (monthly flow median point). However for this thesis such data are not available for the river reaches selected for analysis. For this research it is assumed that the Q_{mp} will be directly related to WUA. Thus, the above mentioned method has been modified and only Q_{mp} has been used instead of WUA.

The other method used is that developed by Tennant in 1976. Recommended minimum flows are based on percentages of the average annual flow (over the record, with different percentages for rainy and dry months).

Details of these curves and interpretation of the results are presented in the following chapter.

5. RESULTS AND DISCUSSION

5.1 Hydrological Analysis

Different hydrological analyses have been performed for the following operational scenarios which are described in Chapter 4.

- Natural Flow — Pre-project
- Scenario -I — 36000 m^3/day Run-off-River
- Scenario -II — 48000 m^3/day Run-off-River
- Scenario -III — 48000 m^3/day (Storage Scheme)

The analyses include selection of flow records (record consistency check), infilling of missing records, flow duration curve analysis (run-off-river schemes) and reservoir simulation study (including revision of reservoir parameters based on size of the storage required). The results of the hydrological analysis for pre and post project are presented in the following sections.

5.1.1 Pre-Project Hydrological Parameters

The analysis of the daily hydrograph, ***Figure 5-1***, demonstrates that the data covered with Q10 is more than that of Q1 and Q5, thus the best maximum flow index variability in this site is represented at Q10.

It should be noted that (as described in Chapter 4) for the run-off-river the maximum flow will not be affected like that of the low flows which will be significantly impacted. For Kibos River it appears the low flow indices are better depicted and represented by Q85 and Q90 than other low flows (Q70 and Q75).

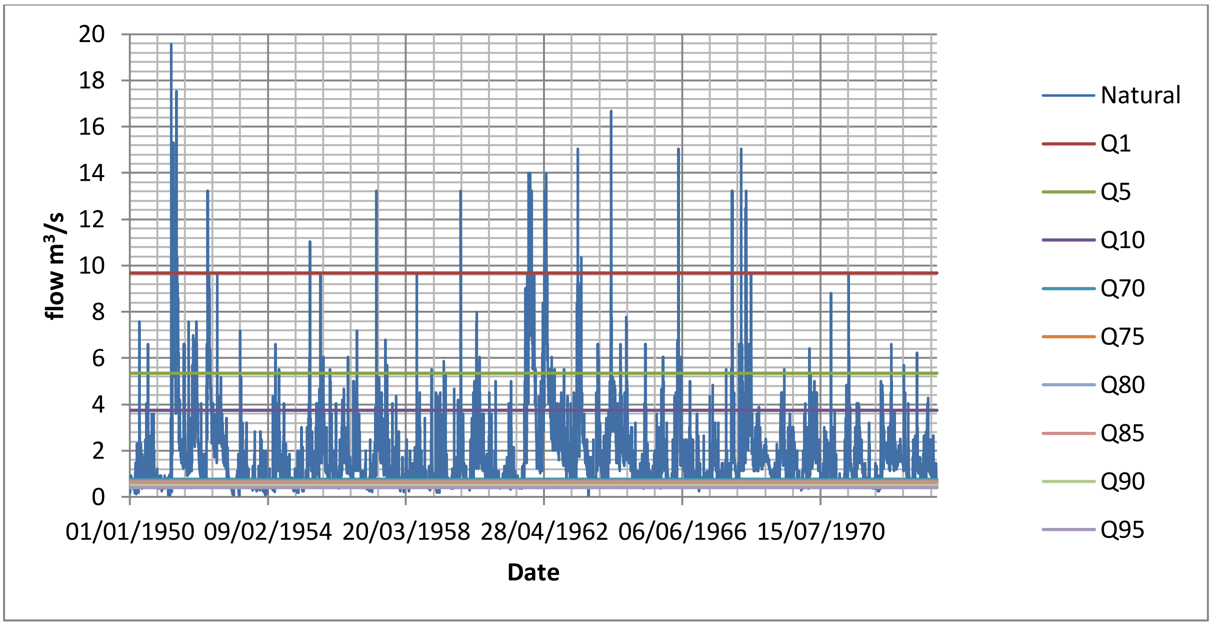


Figure 5-1: Flow Hydrograph and Corresponding indices of flow Variability at 1HA04

5.1.2 Post Project Hydrological Parameters

For the post project hydrological analysis, results can be best presented with flow duration curves as natural flow and modified flows as presented in ***Table 5-1*** and ***Table 5-2***. The results of the hydrological analysis are discussed in detail below.

Table 5-1: Summary of Hydrological Analysis for different scenarios (@ RIVER SECTION 1-1)

EXCEEDANCE Percent	KIBOS FLOW (RIVER SECTION 1-1)			
	NATURAL	OPTION-I	OPTION-II	OPTION-III
	(lps)			
5	5348	4932	4793	4646
10	3748	3331	3192	3100
15	3013	2597	2458	2264
50	1124	707	568	427
60	926	509	371	212
70	751	334	195	212
80	595	229	90	212
85	544	177	38	212
90	495	79	0	212
95	362	0	0	212
98	322	0	0	181
99	247	0	0	135
99.9	75	0	0	49

As shown above flow with higher magnitude will not be affected or changed. However flows with percent exceedance above 15% will be changed signifactly under any of the operation conditions.

Table 5-2: Summary of Hydrological Analysis for different scenarios (@RIVER SECTION 6-6)

Ordinate	EXCEEDANCE Percent	KIBOS FLOW (RIVER SECTION 6-6)			
		NATURAL	OPTION-I	OPTION-II	OPTION-III
		(lps)			
6	5	9669.7	9253.0	9114.1	8835.9
7	10	6776.4	6359.8	6220.9	6018.3
8	15	5448.3	5031.6	4892.8	4578.2
12	50	2032.1	1615.4	1476.6	1455.1
13	60	1674.5	1257.8	1118.9	1005.4
14	70	1357.7	941.0	802.2	819.1
15	80	1167.7	751.0	612.1	734.2
16	85	1073.7	657.0	518.1	692.2
17	90	895.7	479.0	400.3	612.6
18	95	731.4	326.9	326.9	539.2
19	98	581.3	259.8	259.8	472.1
20	99	445.9	199.3	199.3	370.2
23	99.9	135.3	60.5	60.5	127.6

As shown above for the flows at River Section 6-6, the high magnitude flows or flows with lower percent exceedance will not be affected significantly. However, flows with percent exceedance above 50% will be affected to some extent.

5.1.2.1 Run-off-River Schemes

As shown above the run-off-river scheme will only be able to meet the 48,000 m^3/hr water demand 85% of the time. For the remaining 15% of the year the demand will not be met and the river will be dry (with zero flow), this is expected to degrade the environment.

5.1.2.2 Storage Scheme (Option-III 48000 m³/day)

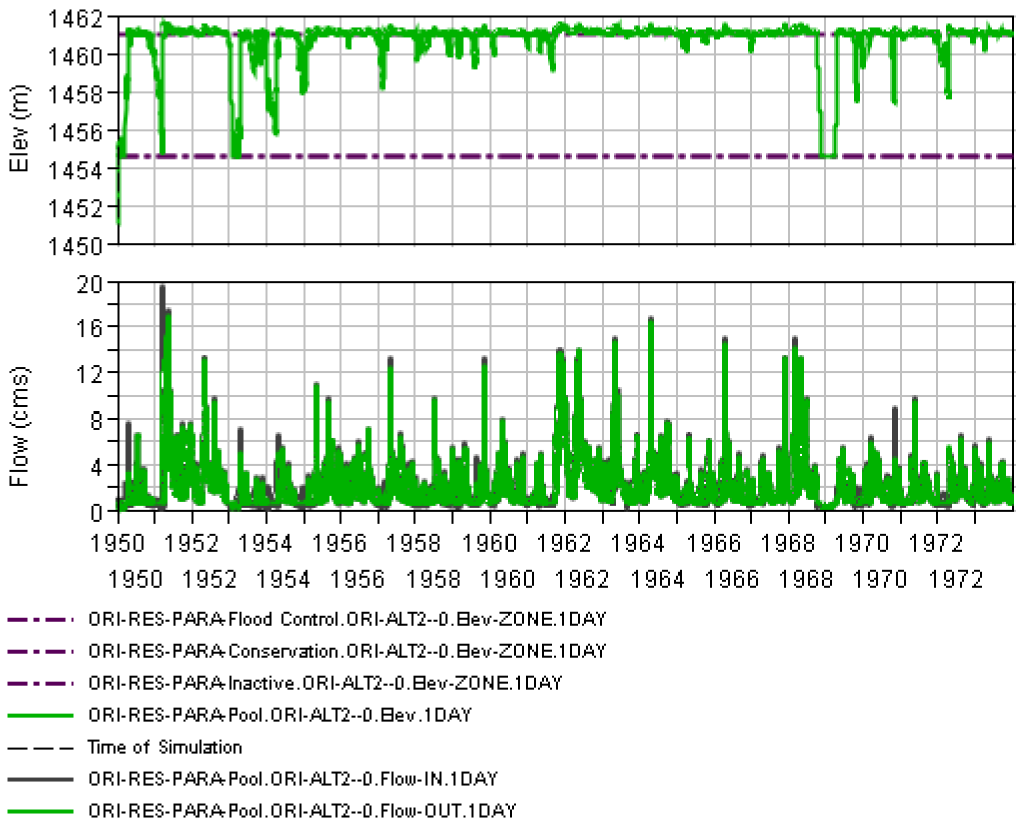


Figure 5-2: Reservoir Operation Simulation Result without Considering any EF

The sediment and reservoir analysis shows that the dead storage level must be raised to a higher elevation of 1484 m.a.m.s.l. and the over flow crest level also need to be raised to 1487.5 m.a.m.s.l. This will result in raising the dam height from it's originally designed 10m height to 16m.

The simulation result shows that if environmental flow is not considered the water supply demand can be met 98.38% of the time. However, the downstream release will be 0m^3/s with 0 % to 22.2 % of the time. This will definitely degrade the ecosystem severely.

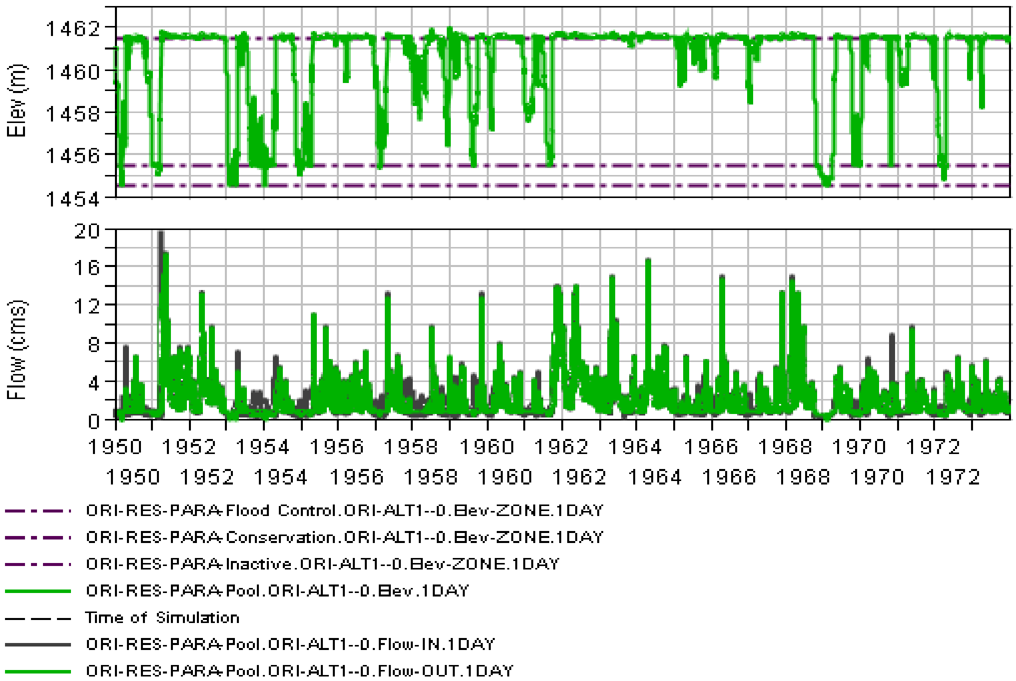


Figure 5-3: Reservoir Operation Simulation Result Considering EF (220 lps minimum)

The reservoir has been simulated to satisfy the water demand at Kajulu and minimum environmental flow during driest year which at least has to be equal or above that of 99% exceeded flow (247 lps). This can be achived through establishment of reservoir rule curve such that both the water supply and environmental demand can be met.

The result of the simulation for this scenario can be summarized as follows:

- Water Supply demand (0.56m^3/s) will be met 92% of the time and 0.25 m^3/s will be available 96.4% of the time.
- Environmental flow 0.247 m^3/s will be available 95.75%

5.1.3 Summary of Hydrological Analysis Result

From purely hydrological point, the best option is run-off-river scheme with capacity of 48000 m^3/hr and operating the system at full capacity whenever water is available by meeting first the environmental flow of 0.20 m^3/s then operate the water treatment plant with whatever is left. However, operationally it will be difficult as the Water Company will be required to pump water from Dunga treatment plant which will incur additional operation cost (electricity cost). Thus, decision has to be made by all concerned stakeholders on the operational sequence (between Dunga and Kajulu Treatment Plant) and other related issues.

5.2 Result of Hydro-Ecological Analysis (RIVER SECTION 1-1)

5.2.1 Option-II 48000 m³/day Run-off-River

5.2.1.1 Spawning and Small Sized Fish

The following figures show seasonal extracts which is one of model outputs. As shown, for spawning and small fishes, the water at which the criteria set will fail is in April 1986. Further computation and interpretation of the model output are presented in Section 5.3.

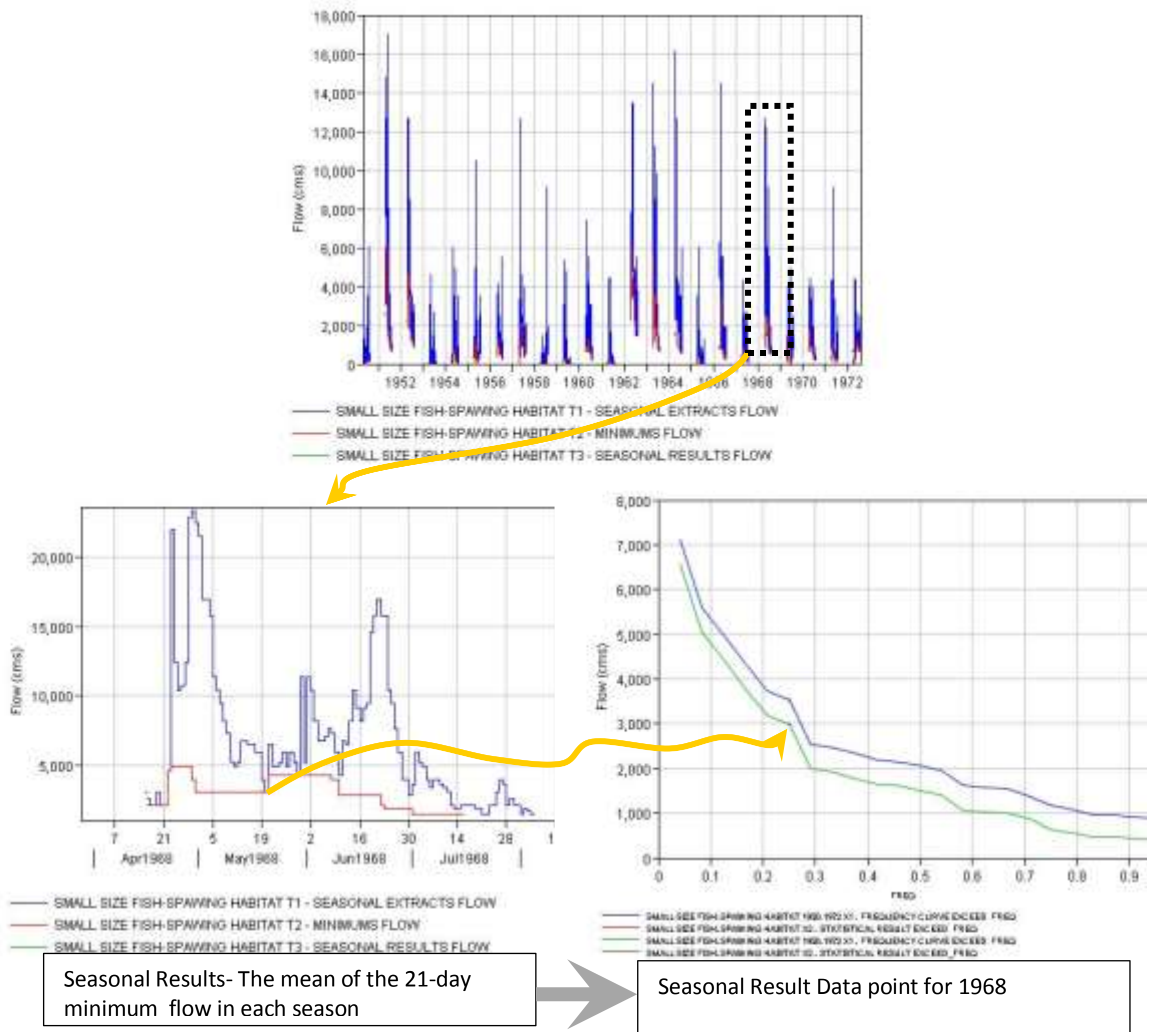


Figure 5-4: Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for <u>Small Size Fish and Spawning</u> (Option-II and River Section 1-1)

5.2.1.2 Rearing and Big Size Fishes

The following figures show seasonal extracts which is one of model outputs. As shown, for rearing and big fishes, the water at which the criteria set will fail is in January 1964. It shows that the damage happens less frequently. Further computation and interpretation of the model output are presented in Section 5.3.

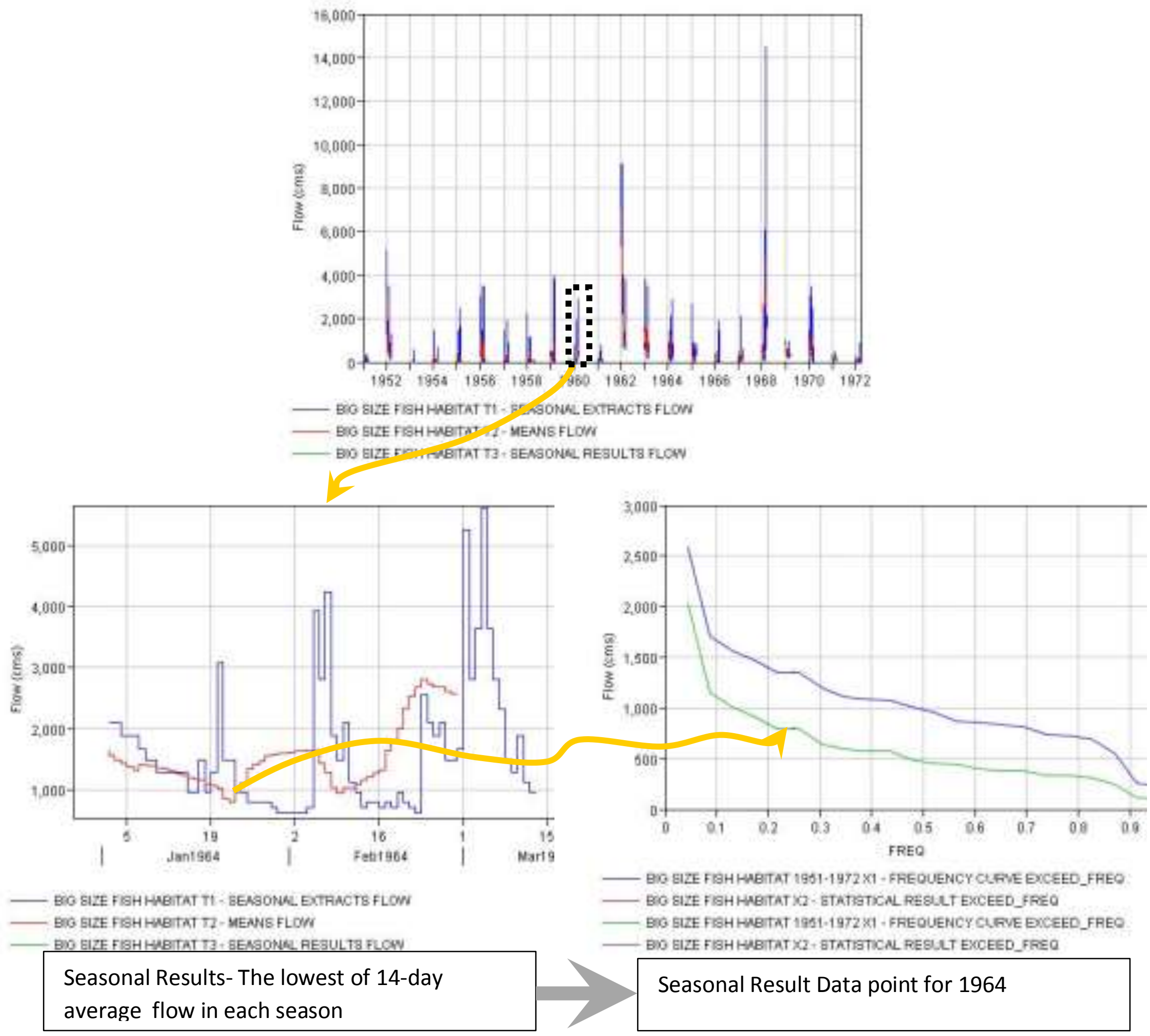


Figure 5-5: Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for <u>Big Sized Fishes and Rearing</u> (Option-II and River Section 1-1)

5.2.2 Option-III 48000 m³/day (Storage Scheme)

5.2.2.1 Micro Invertebrate

The following figures show seasonal extracts from the model analysis results for Option III (Storage Scheme). For micro invertebrate the flooding should happen every two years. As mentioned in Chapter 4, the run-of-river scheme will not change the high flows. However, storage scheme will affect the high flows, as such schemes are meant to store some of flood and normal high flows and use it during dry season. The figure below shows that (except seasonal shift) there are no noticeable difference between the seasonal extract flows, mean flows and seasonal result flows. The main reason is the size of the reservoir, which very small and does not carry water from one water year to the next. Further computation and interpretation of the model output are presented in Section 5.3.

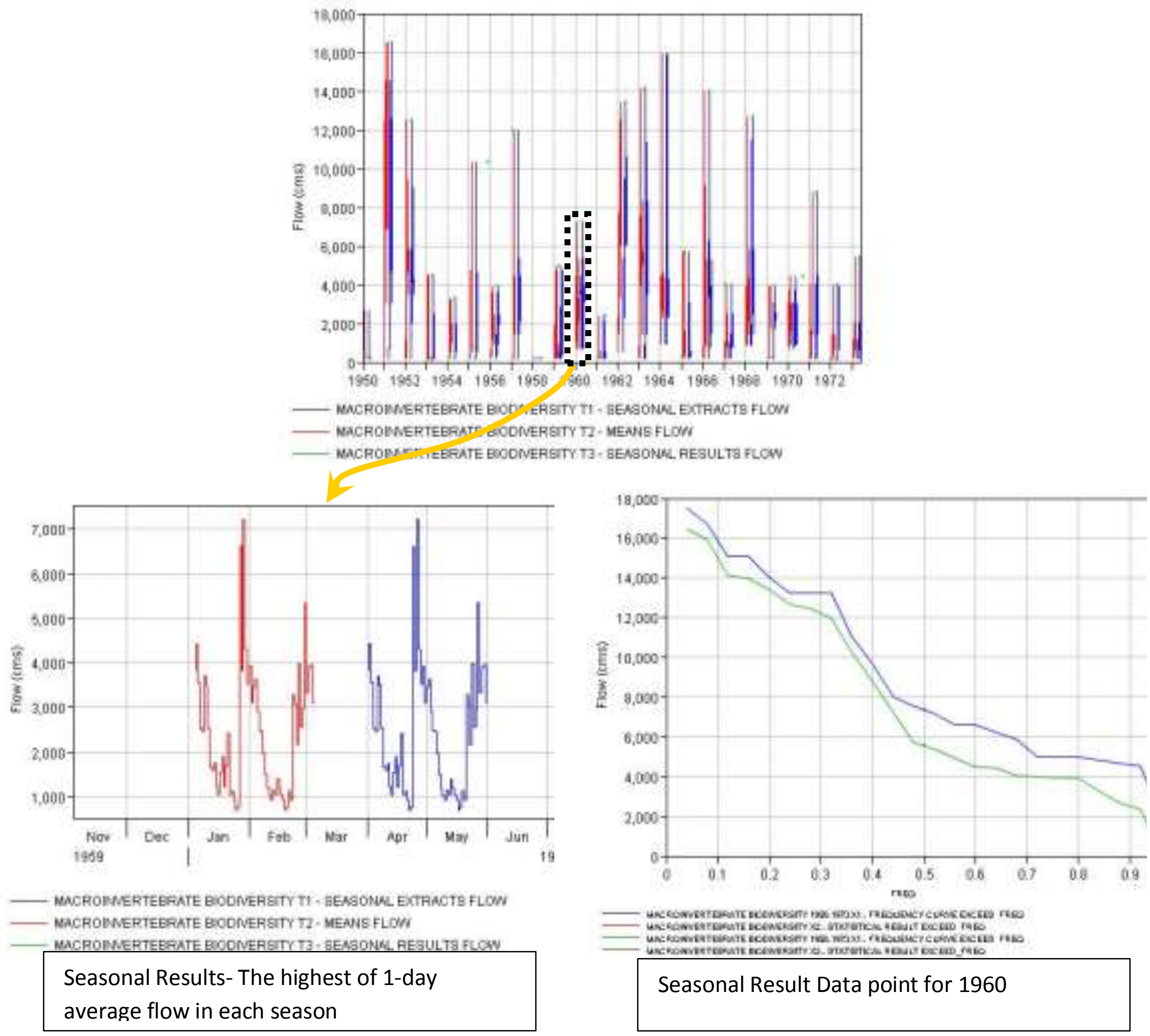


Figure 5-6: Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for <u>Micro Invertebrate</u> (Option-III and River Section 1-1)

5.2.2.1 Wet Land (such as Nyamasaria Swamp)

The following figures show seasonal extracts from the model analysis results for Option III (Storage Scheme). For Wetland (Nyamasaria) with 1 day duration the change is not as such significant. The change will get pronounced as the duration gets longer such (five days and ten days). The five day mean will give us indication on the natural dilution effect in case of high BOD5. The Figure 5-7 presents model result when duration of ten days is considered. This need to be carefully monitored and calibrated as the effluent from Nyalenda will be increased once the current expansion project on Nyalenda Waste Water Stabilization Pond becomes operational. Further computation and interpretation of the model output are presented in Section 5.3.

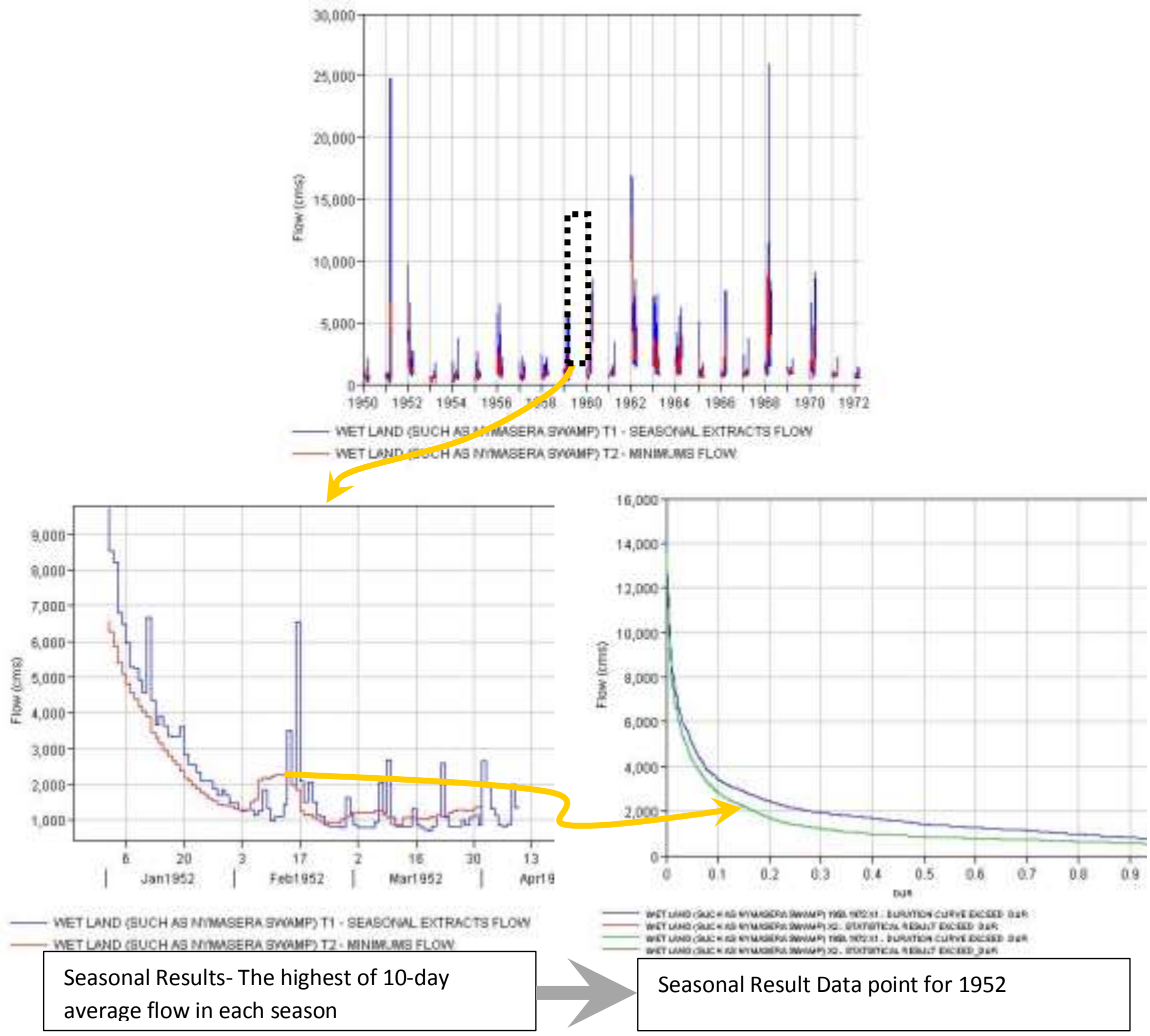


Figure 5-7: Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for <u>Wetland (Nyamasaria Swamp) </u>(Option-III and River Section 6-6)

5.3 Eco-hydro Interpretation

The ecological change has been assessed based on the index given by HEC-EFM and that of Risk Levels Assessment which are based on Key Ecological Variables derived from Davies and Humphries (1996) and method developed by Tennant in 1976. The HEC-EFM has not provided any guide for interpretation of the index values. However, the method derived from Davies and Humphries gives indication on potential risk to each taxa and assists to prescribe environmental flow. These flows can be used for monitoring, which can also at a later stage (based on observed changes) be used for calibration of the model. The result of model analysis for Kibos River at River Section 1-1 and River Section 6-6 is presented in the following sections. The interpretation was also carried out using the methods developed by Tennant in 1976, which gives different critical flows for different season in a year.

5.3.1 Eco-Hydro Interpretation (RIVER SECTION 1-1)

Details of the curves shown in Section 5.2.1 and results of the indicators based on the methods for *River Section 1-1* can be summarised as follows.

Table 5-3: Evaluation of Change based on HEC-EFM (RIVER SECTION 1-1)

Eco-Relationship Indicator	Year	Release Down Stream of Kajulu Diversion Weir (m^3/s)			Natural Flow (m^3/s)	$\%Q_n$		
		Option-I	Option-II	Option-III		Option-I	Option-II	Option-III
Spawning and Small Fish	1968	1.54	1.401	1.425	1.957	79%	72%	73%
Rearing and Big Size Fishes	1964	0.328	0.19	0.213	0.745	44%	26%	29%
Macro invertebrate biodiversity	1960	6.964	6.825	5.537	7.38	95%	93%	85%

As shown above, it can be concluded that if the plant is operated as per arrangement for Option-I, the survival of the other taxa is from optimum to outstanding except big fish taxa.

In case of Option-II the condition for other taxa will almost be in same flow category. However, for big fishes the condition will be severely degrading.

In case of Option-III, the net effect of providing dam for improvement of water supply reliability and allocating e-flow is almost insignificant. The provision of e-flow will not help the ecology of fish rearing and the changed environment will stress big fishes, which ultimately will affect in-channel spawning. Details of graphical presentation of the model result for Option I, II and III at River Section 1-1 are presented in ***Appendix C***. As shown above the wetland has not been considered as indicator at this section (Section 1-1) as the wetland ecology is controlled by the flows from Awach and Kibos.

Table 5-4: Risk Levels Assessment based on Modified Key Ecological Variables Derived from Davies and Humphries (1995) (RIVER SECTION 1-1).

Eco-Relationship Indicator	Year	Release Down Stream of Kajulu Diversion Weir			Qmp	$\%Q_n$		
		Option-I	Option-II	Option-III		Option-I	Option-II	Option-III
Spawning and Small Fish	1968	1.54	1.401	1.425	3.415	45%	41%	42%
Rearing and Big Size Fishes	1964	0.328	0.19	0.213	1.02	32%	19%	21%
Macro invertebrate biodiversity	1960	6.964	6.825	5.537	3.02	231%	296%	187%

		Option-I	Option-II	Option-III
Spawning and Small Fish	1968	High Risk	High Risk	High Risk
Rearing and Big Size Fishes	1964	High Risk	High Risk	High Risk
Macro invertebrate biodiversity	1960	No Risk	No Risk	No Risk

***Note**: All flows are in m^3/sec*

As shown in Table 5-4 the result of environmental risk analysis based on Davies and Humphries approaches, confirms the results obtained from the computation/result of the HEC-EMF. However, of the three methods used to analyse, the result shows that Davies and Humphries is a very conservative method of risk analysis and need to be critically evaluated before its adoption.

The impact of the project for the three operational options have been evaluated based on Tennant method for defining the minimum critical flows. The result of the analysis is presented in ***Table 5-5***. Tennant method uses percent of annual average flow over the record period. The flows derived by applying the proposed percentage by Tennant is conservative and do not evaluate inter annual flow variation. The risk level by Tennant is lower than the result based on other methods used here.

Table 5-5: Summary of Output Comparison Based on Criteria recreation in streams identified by Tennant (1976) (Option I, II and III) (RIVER SECTION 1-1)

Eco-Relationship Indicator	Year	Release Down Stream of Kajulu Diversion Weir			Annual Mean Flow	%		
		Option-I	Option-II	Option-III		Option-I	Option-II	Option-III
Spawning and Small Fish	1968	1.540	1.401	1.425	1.749	88%	80%	81%
Rearing and Big Size Fishes	1964	0.328	0.190	0.213	1.749	19%	11%	12%
Macro invertebrate biodiversity	1960	6.964	6.825	5.537	1.749	398%	390%	317%

Eco-Relationship Indicator	Season Considered	Environmental Risk Classification		
		Option-I	Option-II	Option-III
Spawning and Small Fish	Wet Season	Optimum		
Rearing and Big Size Fishes	Dry season	Fair to Good	Fair to degrading	
Macro invertebrate biodiversity	Wet Season	Flushing or maximum		

Note: *All flows are in m^3/sec*

The result of environmental risk analysis based on Tennant, also confirms the results obtained from the computation/result of the HEC-EMF.

The risk analysis based on the three methods show that, the water that will be left in the river will not be enough for rearing fishes naturally and will not be suitable habitat for big size fishes such as Clarias. Not only the big size fishes will be affected here; as the big size fishes are also sexually mature fishes this will also affect spawning and then finally the whole aquatic habitat in the long term. It should be noted that as the fishes in Kibos River are that of migratory fishes, they are also expected to migrate to the river section upstream of Kajulu water supply diversion intake or to the downstream section of the river (downstream of confluence of Awach and Kibos Rivers).

5.3.2 Eco-Hydro Interpretation (RIVER SECTION 6-6)

Analyses done at River Section 1-1 have also been carried out at River Section 6-6. Details of the curves shown in ***Section 5.2.2*** and results of the indicators based on the above two methods for *River Section 6-6* are summarised below for ease of interpretation:

Table 5-6: Evaluation of Change based on HEC-EFM (RIVER SECTION 6-6)

Eco-Relationship Indicator	Year	Release Down Stream of Kajulu Diversion Weir (m^3/s)			Natural Flow (m^3/s)	$\%Q_n$		
		Option-I	Option-II	Option-III		Option-I	Option-II	Option-III
Small Fish	1968	3.121	2.982	3.006	3.538	88%	84%	85%
Big Size Fishes	1964	0.93	0.792	0.828	1.347	69%	59%	61%
Macro invertebrate biodiversity	1960	12.927	12.788	10.727	13.343	97%	96%	80%
Wet Land (such as Nymasera Swamp)	1952	2.467	2.328	2.203	2.883	86%	81%	76%

As shown above it can be concluded that if the plant is operated as per Option-I and Option-III flows, the survival of all the taxa will be above optimum range.

In case of Option-II the condition for other taxa will almost be in same flow category. However, for big fishes the condition will be marginally lower than Optimum range.

Table 5-7: Summary of Output Comparison Based on Criteria recreation in streams identified by Tennant (1976) (Option I, II and III) (RIVER SECTION 6-6)

Eco-Relationship Indicator	Year	Release Down Stream of Kajulu Diversion Weir			Annual Mean Flow	%		
		Option-I	Option-II	Option-III		Option-I	Option-II	Option-III
Spawning and Small Fish	1968	3.121	2.982	3.006	3.302	95%	90%	91%
Rearing and Big Size Fishes	1964	0.930	0.792	0.828	3.302	28%	24%	25%
Macro invertebrate biodiversity	1960	12.927	12.788	10.727	3.302	391%	387%	325%
Wet Land (such as Nymasera Swamp)	1952	2.467	2.328	2.203	3.302	75%	70%	67%

Eco-Relationship Indicator	Season Considered	Environmental Risk Classification		
		Option-I	Option-II	Option-III
Spawning and Small Fish	Wet Season	Optimum range		
Rearing and Big Size Fishes	Dry season	Good		
Macro invertebrate biodiversity	Wet Season	Flushing or maximum		
Wet Land (such as Nymasera Swamp)	Dry season	Optimum range		

***Note**: All flows are in m^3/sec*

Like the results for River Section 1-1, as shown above, the result of environmental risk analysis based on Tennant method, also confirms the results obtained from the computation/result of the HEC-EMF for River Section 6-6.

Furthermore, analysis based on Tennant shows that river reach downstream of the confluence will not be affect as that of river reach between downstream of Kajulu Water Supply Diversion Intake and confluence of Awach and Kibos rivers.

In general, compared with River Section 1-1 (which represents river section upstream of confluence of Awach and Kibos River) the habitat at downstream section represented by River Section 6-6, the impact of Kajulu water supply project is of no consequence to ecology. Thus, once the project starts running it is expected that most of the fishes will migrate to downstream reach of Kobos River.

5.4 Graphical Presentation

All ecological, hydrological and model analysis results have been compiled and presented graphically using QGIS (Quantum GIS Wroclaw). QGIS is an open source Geographical Information System. QGIS is an easy –to-use GIS software, providing common functions and features.

The main aim of preparing, compiling and presenting the information graphically in GIS is that all information (such as field data, hydrological and model analysis results) can be easily viewed spatially and can be interpreted by different professionals/experts. The compiled information is in non-editable format such that unnecessary or unauthenticated changes to the model result and its dissemination can be controlled.

The Information contained and displayed includes the following and sample of the displayed information are shown in ***Figure 5-8 and Figure 5-9***.

- Summary of model output for River Section 1-1 and Section 6-6
- Detailed hydrological analysis results such as pre and post project hydrographs, flow duration curves
- Reservoir simulation results
- Detailed EFM output for:
    1. Small Fish
    2. Big Fish
    3. Micro Invertebrates

iv. Wetlands

➢ Risk Analysis Results

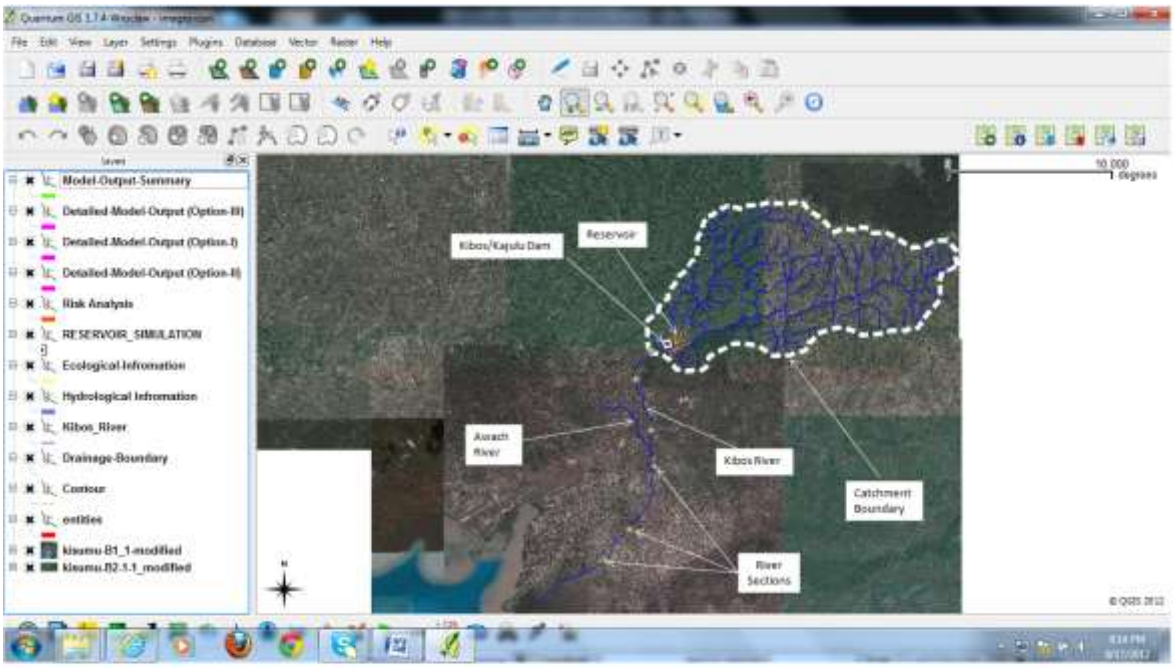


Figure 5-8: General Layout QGIS

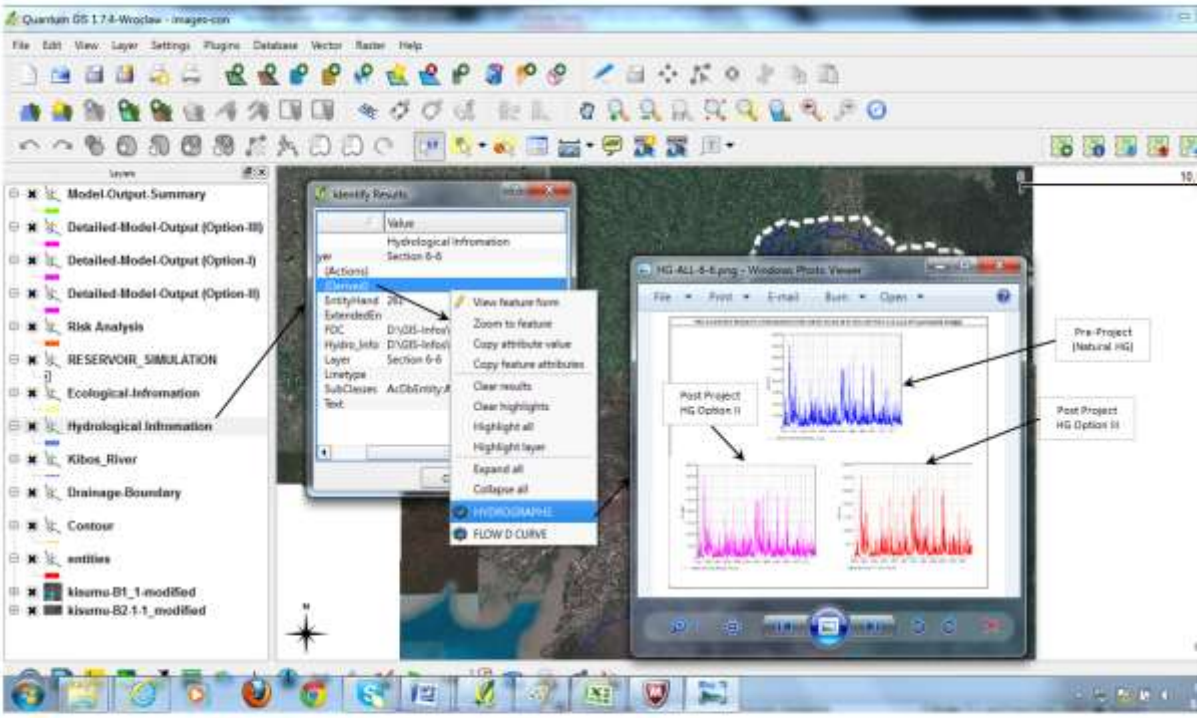


Figure 5-9: Sample output for Displaying Hydrological Information (Pre and Post Hydrographs (HG) for River Section 6-6)

5.5 Flow/s Allocation

This thesis has developed wild life flow requirement (Table 5-5 and 5-7) and operational tools for quantifying environmental flows in the context of Integrated Water Resources Management (IWRM). However, it should be noted that environmental flow requirements are a negotiated trade-off between different water users. The trade-offs involved are inherently case-specific so are the preferences and policies of decision-makers (Korsgaard, 2006). For Kibos, for example, water supply could be vital and a low environmental flows requirement (and thus a low level of ecosystem service provision) might be accepted, or high environmental flows requirements are set in order to maintain valuable ecosystem services. It is all a matter of prioritizing the water uses and the associated trade-offs. Thus, it is up to the water supply utility and the environmental protection agencies to set priority and allocate water for different users accordingly. However, negotiation and discussion has to be initiated at the earliest stage of the project such that the impact can be contained within a limit and unnecessary dispute over water uses can be avoided.

6. SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

The science of advising on environmental flows is relatively young, but several methods have been developed and are being developed. Most of these methods are project specific or basin specific. The methods developed so far cannot be readily applied in Kenya as hydrological and physical characteristics of the rivers/basins for which the methods are developed are different from those of Kenya. Furthermore most of these methods use different modelling tools (software) which might not be possible to be applied in Kenya because of scarcity of data etc. Thus, there is a need to select standard software/s which can be used at national level irrespective of the type of project under consideration.

To address this issue and others, this thesis has developed Ecological Functioning Model using HEC-EFM software and available data. During the modelling process, model results and survey methods were employed to investigate the environmental flows in the downstream of Kajulu Water Supply Diversion on Kibos River. While modelling, the following problems were observed:

- Like most rivers in Africa, inventory of aquatic wildlife of the rivers in Kenya have never been carried out. This made it difficult to select ecological indicators. Thus, irrespective of the size of the river or the project, involvement of other expertise is prudent and a must during planning and execution of any environmental flow assessment.
- There are no national guidelines to be followed to prescribe environmental flow requirements. Thus, it was difficult to evaluate risk level due to diversion of different magnitudes of flows and negotiate trade-off flows or water uses as well as monitoring. For this thesis three evaluation methods have been used for analysing risk and prescribing Environmental flows. These methods include method derived by Davies and Humphries for Risk Level Assessment, based on Modified Key Ecological Variables and Tennant method.

- The modelling software is not suitable for rivers having small discharges. Thus, for small rivers other software which can handle smaller discharges must be selected and used.

Notwithstanding all the above problems, this thesis has developed Ecological Functioning Model using HEC-EFM software and available data. The system was modelled considering the following three different but possible operating scenarios.

- Scenario -I 36000 m^3/day Run-off-River
- Scenario -II 48000 m^3/day Run-off-River
- Scenario -III 48000 m^3/day (Storage Scheme)

The three environmental indicators employed for the research are fish (Labeo, Clarias and Barbus), micro-invertebrates in general and Nyamasaria swamp as wetland.

The methods applied for assessment of risk level are modified method derived from Davies and Humphries (1995) for Risk Levels Assessment based on Modified Key Ecological Variables and the method developed by Tannent in 1976 for identified critical minimum flows required for Fish, Wildlife and Recreation in streams.

6.2 Conclusion

From the result of the analysis it can easily be concluded that the project will have impact on fishes. This impact is pronounced on big fishes such as Labeo and Clarias. In case of dam option the impact could be minimized by allocating environmental flow above 0.25 m^3/sec and use of appropriate reservoir operating curves. However, this may require raising the dam height by a few metres

In case of run-off-river scheme, it is recommended that the treatment plant be operated at lower capacity (36,000 m^3/day) during dry season. This will require overloading of Dunga treatment plant, which will result with higher electricity cost for pumping.

In conclusion, the result presented in here shows that there will be environmental changes on Kibos River due to the proposed intake/diversion weir. Due to the impact of the diversion there will be significant migration of fishes from the affected reach of the river to the reach upstream of the diversion weir and to the river reach downstream of Awach and Kibos confluence. This can only happen if the run-of-river scheme treatment plant is operated at 48,000 m^3/day throughout the year.

If the city is supplied at 36,000 m^3/day as run-of-river scheme and if necessary mitigation measures are taken the water supply project can be compatibly integrated in the ecosystem.

The case study has proved that this modelling software (HEC-EFM) can be used in the Country for Environmental Flow Assessment provided that its present measurement unit is modified such that it can also be used for streams having small discharge.

Furthermore, despite being the economic hub of East Africa and leader in all fields of economy and technology, Kenya lags behind in Environmental flow Assessment and does not have comprehensive plan and frame work to secure the instream flows needed to support the bio-diversity of fresh water life and to sustain ecological functions. To this effect the Country needs to set frameworks for environmental flow assessment and monitoring soon before the already widespread degradation of its river system extends to the ecosystem.

6.3 Recommendation

The ultimate challenge of ecologically sustainable water management is to design and implement a water management program that stores and diverts water for human purposes in a manner that does not cause/affect the ecosystem to a severely degraded level. This question for a balance necessarily implies that there is a limit to the amount of water that can be withdrawn from the river and a limit in the degree to which the shape of a river’s natural flow regime can be altered. To achieve this balance for Kibos the following are recommended

- Install flow measuring gauging Station

- Set framework for Monitoring
- Investigation on bio-diversity of the river, select and develop eco-hydro relationship which can be defended.
- Carry out detailed reservoir investigation using 1 m contour interval map
- Carry out water quality tests downstream of Nyalenda pond to check the effect of reduced discharge during dry period.

Once these and others are collected and synthesised the following six-step process is recommended to be carried out such that sustainable water management can be achieved: This six-step process includes (Richter, 2003):

(1) developing initial numerical estimates of key aspects of river flow necessary to sustain native species and natural ecosystem functions;

(2) accounting for human uses of water, both current and future, through updating the already developed simulation model that facilitates examination of human-induced alterations to river flow regimes;

(3) assessing incompatibilities between human and ecosystem needs with particular attention to their spatial and temporal character;

(4) collaboratively searching for solutions to resolve incompatibilities, if there are any;

(5) conducting water management experiments to resolve critical uncertainties that frustrate efforts to integrate human and ecosystem needs; and

(6) Designing and implementing an easy and adaptive management program to facilitate ecologically sustainable water management for the long term.

If the above listed and other recommendations are implemented, the water supply project can be compatibly integrated in the ecosystem (identified here as ecologically sustainable water management) and should be presumed attainable until conclusively proven otherwise.

7. REFERENCES

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8. 0APPENDICES

Appendix A-(A1) Field Ecological Data Collection Format

Appendix A-(A1) Field Ecological Data Collection Format

Appendix A-(A2) Summary of Field Ecological Data at RIVER SECTION 1-1

Appendix A-(A3) Summary of Field Ecological Data at RIVER SECTION 2-2

Appendix A-(A4) Summary of Field Ecological Data at RIVER SECTION 3-3

Appendix A-(A5) Summary of Field Ecological Data at RIVER SECTION 4-4

Appendix A-(A6) Summary of Field Ecological Data at RIVER SECTION 5-5

Appendix A-(A7) Summary of Field Ecological Data at RIVER SECTION 6-6

Appendix A-(A8) Summary of Field Ecological Data at Nymasera Swamp

Appendix B (B1 to B24) Daily Flow Data for Kibos River from 1950 upto 1973

Appendix C (C1): Statistical Result for Simulation, Project Report and Computational output for RIVER SECTION 1-1

Appendix C (C2): Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for Small Size Fish and Spawning (Option-I and River Section 1-1)

Appendix C (C3): Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for Big Sized Fishes and Rearing (Option-I and River Section 1-1)

Appendix C (C4)Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for Micro Invertebrate (Option-I and River Section 1-1)

Appendix C (C5)Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for Wetland (Nymasera Swamp) (Option-I and River Section 1-1)

Appendix C (C6): Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for Small Size Fish and Spawning (Option-II and River Section 1-1)

Appendix C (C7): Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for Big Sized Fishes and Rearing (Option-II and River Section 1-1)

Appendix C (C8)Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for Micro Invertebrate (Option-II and River Section 1-1)

Appendix C (C9)Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for Wetland (Nymasera Swamp) (Option-II and River Section 1-1)

Appendix C (C10): Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for Small Size Fish and Spawning (Option-III and River Section 1-1)

Appendix C (C11): Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for Big Sized Fishes and Rearing (Option-III and River Section 1-1)

Appendix C (C12)Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for Micro Invertebrate (Option-III and River Section 1-1)

Appendix C (C13)Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for Wetland (Nymasera Swamp) (Option-III and River Section 1-1)

Appendix C (C14): Statistical Result for Simulation, Project Report and Computational output for RIVER SECTION 6-6

APPENDIX A-(A1) Field Ecological Data Collection Format

River ______________________

Reach Local Name ______________________

GPS Point UTM ______________________

Section ID No.

Eco-indicator	Spwaing Period	Mortality Condition	River Morhology	Sub-Element	Statistical Requirement		Ecological Response
Element II - Aquatic Ecosystem							
Fish				Spawning Habitat Abundance	1. Time period=		
					2. No. of days for low flow to be sustained		
					3. Return period		
				Rearing Habitat Abundance	1. Time period=		
					2. No. of days for low flow to be sustained		
					3. Return period		
Wet Land				Rate of Recruitment of Instream Woody Material	1. 1.5-year flow on an annual basis		
					2. 5-year flow on an annual basis		
					3. Average August flow		
					4. Highest stage sustained for 21 days for events that meet Criteria IA-3		

APPENDIX A-(A2) Summary of Field Ecological Data at RIVER SECTION 1-1

River *Kibos River*

Reach Local Name *Downstream of Existing Intake*

GPS Point UTM *X=701841 Y=9999753*

Section ID No. *KIB_SEC_1-1*

Eco-indicator	Spawning Period	Mortality Condition	River Morphology	Sub-Element	Statistical Requirement		Ecological Response
Element II - Aquatic Ecosystem							
1) Labeo 2) Clarias 3) Barbus				Spawning Habitat Abundance	1. Time period=	Fe; Apr-Jun and Sep-Oct	Suitable inchannel fish-spawning. The section is dominated with boulders, rapids etc. The spawning occurs during flood season. For run-off-river the highflows will not be affected. Thus evaluation for spawning might not be required
					2 Highest stage sustained for	21 days	
					3. Return period	Four years	
Labeo is the most abundant at this river section followed by Clarias and Barbus ..\..\Images\River-Reach-X				Rearing Habitat Abundance	1. Time period=	100%	Not-Suitable for floodplain fish-rearing habitat due to step slope which causes turbulences downstream and will also have fish transport downstream. The low flows of the river at this section might be affected, thus the implication on rearing need to be evaluated. The flow to be considered is Kibos only.
					2. No. of days for low flow to be sustained	7-14days	
					3. Return period	Four years	
Wet Land	N/A	N/A	N/A	N/A	1. 1.5-year flow on an annual basis 2. 5-year flow on an annual basis 3. Average August flow 4. Highest stage sustained for 21 days for events that meet Criteria IA-3	N/A	N/A

Intake Site-Abandoned Staff Gauge

Existing Diversion Intake

Intake Site-Abandoned Staff Gauge

Existing Diversion Intake

APPENDIX A-(A3) Summary of Field Ecological Data at RIVER SECTION 2-2

River *Kibos River*

Reach Local Name *Simo*

GPS Point UTM *X=0700949 Y= 9997971*

Section ID No. *KIB_SEC_2-2*

Eco-indicator	Spawning Period	Mortality Condition	River Morphology	Sub-Element	Statistical Requirement		Ecological Response
Element II - Aquatic Ecosystem							
1) Labeo 2) Clarias 3) Barbus				Spawning Habitat Abundance	1. Time period=	Jun-July	The section is located downstream of bridge and it is wide. The river is wide and slope is very gentle gives gentle velocity which makes it suitable for small fishes. Suitable in channel fish-spawning. The spawning occurs during flood season. For run-off-river the highflows will not be affected. Thus evaluation for spawning might not be required
					2. No. of days for low flow to be sustained	21 days	
					3. Return period	Four years	
Labeo is the most abundant at this river section followed by Clarias and Barbus ..\..\Images\River-Reach-X				Rearing Habitat Abundance	1. Time period=	Jan-Dec	At this section the floodplain, if the depth can be sustained for required duration, will give fish-rearing habitat. The low flows of the river at this section might be affected, thus the implication on rearing need to be evaluated. Floodplain-channel Connectivity need to be there through out the year. The flow to be considered is Kibos only.
					2. No. of days for low flow to be sustained	7-14days	
					3. Return period	Four years	
Wet Land	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Longitudinal View down stream of the Section

Shown the river cross section

Section upstream of the river section

APPENDIX A-(A4) Summary of Field Ecological Data at RIVER SECTION 3-3

River *Kibos River*

Reach Local Name *Goba*

GPS Point UTM *X=0701843 Y= 9994868*

Section ID No. *KIB_SEC_3-3*

Eco-indicator	Spwaing Period	Mortality Condition	River Morhology	Sub-Element	Statistical Requirement		Ecological Response
Element II - Aquatic Ecosystem							
1) Clarias 2) Barbus 3) Labeo				Spawning Habitat Abundance	1. Time period=	Feb-Mar (timing information might not be accurate)	The section is located upstream of bridge and it is wide. The river is wide and slope is very gentle gives gentle velocity which makes it suitable for small fishes. Suitable in channel fish-spawning. The spawing occurs during flood season. For run off-river the highflows will not be affected. Thus evaluation for spawning might not be required
					2. No. of days for low flow to be sustained	21 days	
					3. Return period	Four years	
Clarias is the most abondant at this river section followed by Barbus and Labeo ..\..\Images\River-Reach-X				Rearing Habitat Abundance	1. Time period=	Jan-Dec	The condition at this section is almost similar to that of section 2-2. Thus, all modeling parameters and results for section 2-2 might also applied. No independent modelling for this section is required
					2. No. of days for low flow to be sustained	7-14days	
					3. Return period	Four years	
Wet Land	N/A	N/A	N/A	N/A	N/A	N/A	N/A

River Section 3-3

Bridge down Stream of Section 3-3

APPENDIX A

Page 4 of 8

APPENDIX A-(A5) Summary of Field Ecological Data at RIVER SECTION 4-4

River *Kibos River*

Reach Local Name *Kibos (Close to the Kibos Sugar Factory)*

GPS Point UTM *X=0702081 Y= 9992657*

Section ID No. *KIB_SEC_4-4*

Eco-indicator	Spwaing Period	Mortality Condition	River Morhology	Sub-Element	Statistical Requirement		Ecological Response
Element II - Aquatic Ecosystem							
1) Barbus				Spawning Habitat Abundance	1. Time period=	Jun-July	The section is located close to Kibos Sugar Factory. The river is wide and slope is very gentle gives gentle-noticeable velocity which makes it suitable for small fishes. Suitable in channel fish-spawning. The spawning occurs during flood season. For run-off-river the highflows will not be affected. Thus evaluation for spawning might not be required
2) Clarias					2. No. of days for low flow to be sustained	21 days	
3) Labeo					3. Return period	Four years	
Barbus is the most abondant at this river section followed by Clarias and Labeo				Rearing Habitat Abundance	1. Time period=	Oct-Nov	Unlike two of the upstream section here the rearing is inhannel continues flow need to be provided. The low flows of the river at this section might be affected, thus the implication on rearing need to be evaluated. The flow to be considered is Kibos and Awach.
					2. No. of days for low flow to be sustained	60days	
..\..\Images\River-Reach-X					3. Return period	Four years	
Wet Land	N/A	N/A	N/A	N/A	N/A	N/A	N/A

River Section 4-4 (looking downstream)

APPENDIX A

Page 5 of 8

APPENDIX A-(A6) Summary of Field Ecological Data at RIVER SECTION 5-5

River *Kibos River*

Reach Local Name *Kanu Plain*

GPS Point UTM *X=0700545 Y= 9988897*

Section ID No. *KIB_SEC_5-5*

Eco-indicator	Spwaing Period	Mortality Condition	River Morhology	Sub-Element	Statistical Requirement		Ecological Response
Element II - Aquatic Ecosystem							
1) Labeo and Barbus 2) Clarias				Spawning Habitat Abundance	1. Time period=	March	The section is located close to Kibos Sugar Factory. The river is wide and slope is very gentle gives gentle-noticeable velocity which makes it suitable for small fishes. Suitable in channel fish-spawning The spawing occurs during flood season. For run-off-river the highflows will not be affected. Thus evaluation for spawning might not be required
					2. No. of days for low flow to be sustained	365 days	
					3. Return period	Four years	
Labeo and Barbus is the most abondant at this river section followed by Clarias ..\ \Images\River-Reach-X				Rearing Habitat Abundance	1. Time period=		The low flows of the river at this section might be affected, thus the implication on rearing need to be evaluated. The flow to be considered is Kibos and Awach.
					2. No. of days for low flow to be sustained		
					3. Return period		
Wet Land	N/A	N/A	N/A	N/A	N/A	N/A	N/A

River Section 4-4 (looking downstream)

APPENDIX A

Page 6 of 8

APPENDIX A-(A7) Summary of Field Ecological Data at RIVER SECTION 6-6

River *Kibos River*

Reach Local Name *Nymasera*

GPS Point UTM *X=0699035 Y= 9986943*

Section ID No. *KIB_SEC_6-6*

Eco-indicator	Spwaing Period	Mortality Condition	River Morhology	Sub-Element	Statistical Requirement		Ecological Response
Element II - Aquatic Ecosystem							
1) Labeo and Barbus 2) Clarias				Spawning Habitat Abundance	1. Time period=	March-April	The section is located upstream of bridge (on Kisumu Busia Road) and it is wide. The river is wide and slope is very gentle gives gentle velocity which makes it suitable for small fishes. The spewing occurs during flood season. For run-off-river the highflows will not be affected. Thus evaluation for spawning might not be required
					2. No. of days for low flow to be sustained	365 days	
					3. Return period	Four years	
Labeo and Barbus is the most abondant at this river section followed by Clarias ..\ \Images\River-Reach-X				Rearing Habitat Abundance	1. Time period=		The low flows of the river at this section might be affected, thus the implication on rearing need to be evaluated. The flow to be considered is Kibos and Awach.
					2. No. of days for low flow to be sustained		
					3. Return period		
Wet Land	N/A	N/A	N/A	N/A	1. 1.5-year flow on an annual basis	N/A	
					2. 5-year flow on an annual basis		
					3. Average August flow		
					4. Highest stage sustained for 21 days for events that meet Criteria IA-3		

River Section 6-6 (looking upstream)

Bridge located downstream of Section 6-6

APPENDIX A-(A8) Summary of Field Ecological Data at Nymasera Swamp

River *Kibos River*

Reach Local Name *Nymasera Swamp*

GPS Point UTM

Section ID No. *Area*

Eco-indicator	Spwaing Period	Mortality Condition	River Morhology	Sub-Element	Statistical Requirement		Ecological Response
Element II - Aquatic Ecosystem							
1) Clarias, Labeo and Barbus The data on this was difficult to collect due to inaccessibility and inhabited. Thus, difficult to get information. However, from general commencing it is beloved all fish types upstream of the swamp are belied to existing also in the ..\..\Images\River-Reach-X				Spawning Habitat Abundance	1. Time period=	March-April and Sep to D	Water exchange between river and wetland areas helps to maintain wetland water quality. Exchange is especially important between mid-May and Mid-September. Active exchange for 30% of time in this season will support healthy conditions. The low flows of the river at this section might be affected, thus the implication on rearing need to be evaluated. The flow to be considered is Kibos and Awach.
					2. No. of days for low flow to be sustained	10days	
					3. Return period	15% from Kibos the remaining 15% from Awach	
				Rearing Habitat Abundance	1. Time period=		
					2. No. of days for low flow to be sustained		
					3. Return period		
					Nyalenda WWSP (Located upstream of the Nymasera Swamp Kibos and Awach river have significant contribution in dilution of the effluent from the Pond)		

Nyalenda WWSP (Located upstream of the Nymasera Swamp Kibos and Awach river have significant contribution in dilution of the effluent from the Pond)

Location of Nymasera Swamp-Nyalenda Pond-Kibos River

YEAR : ***1950***

APPENDIX B (B1) Daily Flow Data for Kibos River

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	0.7509	0.4490	0.9776	0.4045	0.4954	0.6996	4.0487	1.1240	1.8618	0.8358	0.4954	0.6996	1.0700
2	0.7509	0.4490	1.0592	0.4045	2.3173	0.5938	2.4826	0.8358	1.8618	0.7509	0.4954	0.6996	1.0600
3	0.8358	0.4045	1.0570	0.4045	0.7509	0.5938	1.8618	0.7509	1.2316	0.6996	0.5938	0.6458	0.8200
4	0.2466	0.4045	0.9434	0.2830	0.5938	0.4954	1.4650	0.6996	1.0222	0.6458	0.4954	0.6458	0.6600
5	0.1802	0.4045	0.9472	0.2466	0.5938	0.4954	1.4650	0.6458	2.3173	0.6996	0.4954	0.6458	0.7600
6	0.5938	0.4045	1.4796	0.1802	0.4954	0.9262	0.9262	0.6996	1.3452	0.6458	0.4490	0.9262	0.7600
7	0.5938	0.4954	0.9584	0.6458	0.4954	0.5437	1.1240	0.5938	1.4650	0.5938	0.4954	0.9262	0.7400
8	0.5437	0.4954	0.8253	0.5938	0.4045	0.7509	0.8358	0.5938	0.9262	0.5938	0.4045	0.6996	0.6400
9	0.4954	0.4490	0.8577	0.6996	0.4045	1.1240	0.7509	0.5938	0.9262	0.7509	0.4045	0.4045	0.6600
10	0.4954	0.4045	0.2123	0.5938	0.5938	0.6458	0.6996	0.6458	0.7509	0.6458	0.3620	0.4954	0.5500
11	0.4954	0.4045	0.4045	0.6996	0.5938	1.7232	0.6458	0.9262	1.0222	0.5938	0.3620	0.3620	0.6900
12	0.4954	0.3620	0.3620	0.8358	0.4490	1.3452	0.6996	0.9262	0.9262	0.5938	0.3620	0.3215	0.6400
13	0.4490	0.3620	0.1228	1.1240	0.3620	0.7509	0.6996	0.7509	2.4826	0.5938	0.8358	0.3215	0.7400
14	0.4954	0.3215	0.1802	0.9262	0.3620	0.7509	2.0070	0.6458	1.7232	0.5938	0.7509	0.2830	0.7500
15	0.4954	0.3620	0.3620	0.6458	0.3620	0.6996	0.7509	2.6548	2.6548	0.5938	0.7509	0.2466	0.8800
16	0.9262	0.3215	0.4045	7.5773	0.7509	0.6996	0.7509	1.4650	1.3452	0.5437	0.7509	0.2466	1.3200
17	0.6458	0.3215	0.4954	2.6548	0.6458	0.9262	2.3173	1.0222	2.3173	0.4954	0.6996	0.5938	1.0900
18	0.5938	0.4045	0.5938	1.7232	1.8618	0.6996	6.6087	0.9262	3.6014	0.6996	0.7509	0.5938	1.5900
19	0.8358	0.3620	0.6996	3.2139	0.9262	0.6458	6.6087	0.8358	1.7232	0.6996	0.7509	0.5938	1.4900
20	0.6458	0.4045	1.0222	3.2139	1.0222	2.4826	2.6548	0.8358	2.0070	0.5938	0.7509	0.5938	1.3500
21	0.5938	0.3620	2.3173	1.8618	0.6996	0.9262	1.4650	0.7509	1.5909	0.5938	0.7509	0.5938	1.0400
22	0.8358	0.5437	2.3173	1.4650	0.9262	0.8358	1.8618	0.6996	1.8618	0.5938	0.7509	0.5938	1.1100
23	0.6996	0.4954	1.3452	1.1240	0.7509	1.8618	1.3452	0.6458	2.0070	0.7509	0.7509	0.5938	1.0300
24	0.5938	0.4490	0.6996	0.8358	1.4650	0.9262	1.1240	0.5938	1.4650	0.9262	0.9262	0.5938	0.8800
25	0.5938	0.4490	0.4954	0.6458	0.7509	1.0222	1.0222	0.5938	1.2316	1.1240	0.7509	0.5437	0.7700
26	0.5437	0.3620	2.0070	0.6458	0.6458	0.9262	1.0222	0.5938	1.1240	1.1240	0.6996	0.4954	0.8500
27	0.5437	0.3215	1.0222	0.5938	0.9262	0.8358	0.7509	1.4650	0.9262	1.2316	0.6996	0.4954	0.8200
28	0.4954	0.1504	0.6996	0.5437	1.4650	1.8618	0.7509	3.6014	0.8358	0.6996	0.6996	0.4954	1.0200
29	0.4954		0.5437	0.4954	0.9262	1.2316	0.7509	1.7232	0.8358	0.5938	0.9262	0.4954	0.8200
30	0.4954		0.3620	0.4954	0.7509	1.1240	0.6996	1.4650	0.8358	0.5938	0.7509	0.4954	0.7300
31	0.4954		0.3620		0.7509		0.7509	1.4650		0.4954		0.4954	0.6900
MIN.	0.1802	0.1504	0.1228	0.1802	0.3620	0.4954	0.6458	0.5938	0.7509	0.4954	0.3620	0.2466	
MAX.	0.9262	0.5437	2.3173	7.5773	2.3173	2.4826	6.6087	3.6014	3.6014	1.2316	0.9262	0.9262	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B

Page 1 of 24

APPENDIX B (B2) Daily Flow Data for Kibos River

YEAR : **1951**

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	0.4954	0.4954	0.4045	1.1240	9.2422	9.2422	2.6548	1.5909	1.7232	3.6014	1.2316	6.7979	3.2200
2	0.4954	0.4490	0.4045	0.7509	9.6802	8.6015	2.6548	1.5909	1.8618	2.4826	1.1240	2.3173	2.7000
3	0.4954	0.4045	0.3620	0.2123	8.1852	8.1852	2.3173	1.4650	1.8618	7.5773	1.1240	2.6548	2.9000
4	0.4490	0.4490	0.3620	2.0070	7.3791	9.2422	2.0070	1.2316	1.5909	2.6548	1.4650	2.3173	2.6000
5	0.4490	0.4490	0.1802	10.3532	6.6087	7.5773	2.0070	1.2316	1.4650	2.1588	1.1240	2.3173	2.9900
6	0.4045	0.5938	0.3620	6.6087	5.1775	7.7777	2.0070	1.4650	1.5909	1.4650	1.8618	2.6548	2.6600
7	0.4045	0.5938	0.9584	2.8341	7.7777	8.1852	2.0070	1.2316	1.3452	2.3173	1.4650	2.3173	2.6200
8	0.4045	0.4954	0.4045	3.4148	6.2371	7.9804	1.7232	1.7232	1.2316	1.4650	2.1588	2.1588	2.4500
9	0.4045	0.4954	0.5437	1.8618	5.6968	8.6015	1.7232	4.0487	1.7232	1.2316	3.4148	3.4148	2.7600
10	0.4045	0.4954	0.7509	7.5480	5.5214	7.5773	2.4826	6.6087	1.4650	1.1240	4.5558	2.4826	3.4200
11	0.3620	0.4954	0.5437	13.2341	6.6087	6.9894	1.7232	4.0487	1.7232	1.0222	5.6968	2.4826	3.7400
12	0.3620	0.4490	0.4954	9.2422	6.6087	6.6087	1.7232	2.8341	1.3452	1.0222	4.8430	3.4148	3.2500
13	0.3620	0.4490	0.3215	7.7777	5.6968	6.0547	1.7232	3.2139	1.2316	1.4650	4.0487	4.0487	3.0300
14	0.4045	0.4490	0.1802	6.6087	5.5214	6.2371	1.5909	2.3173	1.1240	2.0070	3.2139	3.6014	2.7700
15	0.5437	0.4954	0.0749	10.1267	3.6014	5.6968	1.4650	2.3173	1.1240	1.4650	4.3592	3.6014	2.9100
16	0.9262	0.4490	0.4045	10.3532	3.6014	6.2371	1.4650	2.3173	0.9262	1.3452	2.8341	5.0091	2.9900
17	0.6458	0.4954	0.4490	13.2341	4.6794	4.2027	1.4650	2.0070	1.2316	1.2316	2.6548	5.6968	3.1700
18	0.4954	0.8358	0.4490	8.1852	3.6014	3.6014	1.4650	3.2139	0.9262	3.0204	4.0487	5.3483	2.9300
19	0.5938	0.6996	0.4954	10.3532	8.6015	2.6548	1.4650	6.6087	0.9262	1.8618	4.3592	6.2371	3.7400
20	0.5938	0.5938	0.5437	15.3189	10.5818	2.4826	2.4826	5.6968	1.0222	1.8618	5.1775	5.6968	4.3400
21	0.5437	0.5437	0.4954	13.2341	7.7777	2.3173	2.3173	4.3592	0.9262	1.4650	6.9894	5.1775	3.8500
22	0.5437	0.1504	0.4490	9.6802	6.2371	2.8341	1.7232	4.0487	0.9262	2.8341	5.1775	4.6794	3.2700
23	0.5437	0.0749	0.4490	13.2341	17.5314	2.3173	1.4650	3.4148	1.7232	3.4148	4.3592	4.0487	4.3800
24	0.4954	0.0976	1.0222	9.6802	10.8125	2.1588	1.8618	3.2139	1.4650	2.0070	4.0487	4.0487	3.4100
25	0.4954	0.0749	1.4650	13.2341	9.2422	2.0070	1.4650	2.6548	1.4650	2.0070	5.0091	6.4217	3.8000
26	0.4490	0.4490	3.4148	10.8125	8.1852	2.6548	1.4650	2.4826	1.4650	1.4650	3.8971	7.5773	3.6900
27	0.4045	0.4045	0.5938	11.5172	7.3791	2.8341	1.4650	2.6548	1.1240	1.4650	3.6014	6.6087	3.3400
28	0.4045	0.4045	19.5703	8.6015	9.2422	4.0487	1.4650	2.3173	3.2139	1.2316	3.4148	5.6968	4.9700
29	0.4490		1.3452	9.2422	8.3923	4.2027	1.4650	1.8618	2.3173	1.1240	2.8341	5.6968	3.5400
30	0.4045		1.4650	13.2341	10.3532	2.8341	1.3452	1.8618	1.4650	1.2316	2.6548	6.6087	3.9500
31	0.4045		1.8618		9.0265		1.4650	1.7232		1.2316		5.6968	3.0600
MIN.	0.3620	0.0749	0.0749	0.2123	3.6014	2.0070	1.3452	1.2316	0.9262	1.0222	1.1240	2.1588	
MAX.	0.9262	0.8358	19.5703	15.3189	17.5314	9.2422	2.6548	6.6087	3.2139	7.5773	6.9894	7.5773	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B (B3) Daily Flow Data for Kibos River

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	5.6968	1.1240	0.7509	1.8618	7.5773	4.3592	2.4826	2.0070	2.3173	3.6014	1.4650	1.4650	2.8900
2	5.0091	1.0222	0.6996	1.3452	5.8746	4.2027	2.4826	1.7232	2.3173	2.6548	1.3452	1.3452	2.5000
3	4.8430	1.0222	0.6996	1.0222	5.1775	3.8971	2.3173	1.4650	3.2139	2.4826	1.3452	1.2316	2.3900
4	4.0487	1.0222	0.6996	0.9262	6.6087	3.7480	2.0070	1.5909	2.8341	2.1588	1.3452	1.0222	2.3300
5	3.8971	1.0222	0.6996	0.7509	9.0265	3.8971	2.3173	1.5909	2.4826	3.2139	1.4650	1.1240	2.6200
6	3.6014	0.9262	0.9262	0.7509	7.5773	3.6014	2.0070	3.4148	3.2139	2.6548	1.4650	1.0222	2.6000
7	3.2139	1.0222	1.5909	0.8358	6.2371	3.6014	1.8618	4.0487	3.0204	2.6548	1.3452	0.8358	2.5200
8	3.2139	1.3452	0.9262	1.4650	6.7979	3.2139	1.7232	9.6802	3.4148	2.0070	1.3452	0.9262	3.0000
9	3.0204	1.0222	1.8618	1.0222	6.9894	2.3173	1.8618	8.1852	4.0487	2.0070	1.4650	0.8358	2.8900
10	2.8341	0.8358	0.8358	1.0222	6.9894	2.4826	2.3173	5.1775	3.6014	2.0070	1.2316	0.8358	2.5100
11	4.0487	0.9262	0.7509	0.7509	9.6802	2.6548	2.3173	4.5181	2.8341	1.7232	1.7232	0.8358	2.7300
12	2.6548	0.9262	0.7509	0.6996	8.1852	2.4826	2.1588	4.0487	2.4826	2.3173	1.3452	0.8358	2.4100
13	2.3173	1.1240	0.7509	0.6996	8.1852	2.4826	3.2139	3.8971	2.4826	1.7232	1.3452	0.8358	2.4200
14	2.4826	2.3173	0.7509	1.4650	6.9894	2.6548	2.6548	3.8971	3.2139	1.5909	1.3452	0.6996	2.5100
15	2.3173	1.3452	1.1240	4.8430	9.0265	2.4826	2.1588	3.8971	4.0487	1.4650	1.4650	0.6996	2.9100
16	2.1588	4.0487	0.7509	2.8341	8.1852	2.4826	2.4826	3.8971	4.8430	1.7232	1.3452	0.6996	2.9500
17	2.1588	1.3452	0.6996	6.6087	6.2371	2.4826	2.0070	3.2139	5.1775	1.5909	3.4148	0.6458	2.9700
18	2.1588	1.1240	0.6458	4.8430	5.6968	4.0487	1.8618	2.8341	4.3592	1.8618	1.4650	0.6996	2.6300
19	2.3173	1.4650	0.5938	3.6014	5.1775	3.6014	2.1588	2.8341	3.8971	1.7232	1.1240	0.6996	2.4300
20	1.8618	1.1240	0.7509	2.6548	5.1775	3.2139	2.4826	2.4826	3.4148	1.5909	1.1240	0.5938	2.2100
21	1.7232	0.9262	1.1240	3.6014	6.4217	3.0204	1.8618	4.0487	3.2139	1.7232	0.9262	0.5938	2.4300
22	1.7232	0.9262	1.8618	2.4826	5.1775	2.6548	2.1588	2.8341	3.0204	1.7232	0.8358	0.5938	2.1700
23	1.5909	0.7509	0.8358	4.3592	5.8746	3.0204	1.7232	2.6548	2.6548	1.4650	1.2316	0.5437	2.2300
24	1.4650	0.7509	0.7509	4.2027	4.8430	4.0487	1.8618	3.2139	2.4826	1.3452	1.1240	0.5437	2.2200
25	1.4650	0.7509	0.7509	13.2341	5.1775	2.8341	2.0070	4.0487	2.3173	2.6548	1.2316	0.5437	3.0800
26	1.4650	0.7509	0.7509	10.5818	4.6794	2.4826	3.6014	4.3592	2.4826	1.4650	1.7232	0.5437	2.9100
27	1.3452	0.6996	0.9262	8.6015	4.8430	2.4826	2.4826	3.6014	3.6014	1.3452	2.1588	0.5437	2.7200
28	1.2316	1.3452	0.7509	13.2341	4.8430	2.3173	2.1588	4.0487	2.1588	1.3452	2.0070	0.5437	3.0000
29	1.3452	0.9262	0.9262	11.5172	4.3592	2.3173	2.0070	3.4148	2.6548	1.4650	1.5909	0.4954	2.7500
30	1.2316		0.9262	9.9024	4.0487	2.0070	1.8618	3.6014	2.4826	1.4650	1.3452	0.4045	2.6600
31	1.1240		0.7509		4.8430		1.8618	2.8341		1.5909		0.4045	1.9200
MIN.	1.1240	0.6996	0.5938	0.6996	4.0487	2.0070	1.7232	1.4650	2.1588	1.3452	0.8358	0.4045	
MAX.	5.6968	4.0487	1.8618	13.2341	9.6802	4.3592	3.6014	9.6802	5.1775	3.6014	3.4148	1.4650	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B (B4) Daily Flow Data for Kibos River

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	0.4045	0.1228	0.4954	0.1504	1.1240	0.5938	1.0222	0.6458	0.5437	0.6996	1.3452	2.4826	0.8000
2	0.4045	0.0976	0.4954	0.0749	0.7509	0.4954	0.6996	0.5938	0.7509	0.5437	0.8358	1.0222	0.5600
3	0.4490	0.0976	0.5437	0.0749	1.7232	0.6458	0.8358	0.4954	0.6996	0.4490	0.6458	0.8358	0.6200
4	0.4490	0.0976	0.5938	0.0749	1.0222	0.9262	0.7509	0.4045	0.7509	0.3620	0.8358	0.5437	0.5700
5	0.4954	0.0749	0.5938	0.0547	1.4650	0.4954	0.6458	0.4045	0.5938	0.5437	0.5938	0.5938	0.5500
6	0.4954	0.4954	0.5938	0.0547	0.4954	0.6996	0.5938	0.4490	0.4954	0.4045	0.5437	0.4954	0.4800
7	0.4490	0.4954	0.8358	0.6996	1.4650	1.4650	0.5938	0.5938	0.4045	0.3620	0.5437	0.4954	0.7000
8	0.4045	0.4490	0.9262	0.5938	1.3452	2.0070	0.5938	0.4490	0.3620	0.3620	0.4954	0.4490	0.7000
9	0.3620	0.4954	0.7509	0.4490	3.2139	1.0222	0.4954	0.4954	0.3620	0.2466	0.5938	0.3620	0.7400
10	0.3620	0.4954	0.6996	0.5437	2.8341	2.0070	0.5437	0.4490	0.3620	0.2466	0.4954	0.3620	0.7800
11	0.3215	0.4490	0.6458	1.4650	1.3452	1.1240	0.5938	0.4490	0.5938	0.4490	0.4954	0.4954	0.7000
12	0.3215	0.4954	0.5938	1.1240	1.3452	0.8358	0.5437	0.4490	0.3620	0.4045	0.3215	0.5938	0.6200
13	0.3620	0.4490	1.1240	0.4954	0.9262	0.6996	1.2316	0.4490	0.4954	0.2830	0.2830	0.3620	0.6000
14	0.3215	0.4954	0.6458	7.1831	0.7509	0.5938	0.6458	0.4490	0.4045	0.4045	0.3215	0.3620	1.0500
15	0.2830	0.4954	0.5938	3.2139	0.6996	0.6458	0.5437	0.7509	1.8618	0.6458	0.3215	0.3215	0.8600
16	0.2830	0.4490	0.5437	0.5938	0.6458	0.5938	0.6458	0.4954	1.3452	0.5938	0.7509	0.2466	0.6000
17	0.2830	0.4490	0.5437	2.3173	0.5938	1.0222	0.5938	0.4045	1.4650	0.4954	0.6458	0.2466	0.7600
18	0.2123	0.4490	0.5437	1.1240	0.5938	2.4826	0.5437	0.4954	0.8358	0.3620	0.4954	0.9262	0.7600
19	0.1802	0.4490	0.5437	0.6996	0.5938	0.9262	0.4954	0.5938	1.2316	0.5938	0.9262	0.5437	0.6500
20	0.1504	0.4045	0.5437	0.6996	0.5437	0.7509	0.5437	0.6996	2.8341	0.5437	2.8341	0.6458	0.9300
21	0.1504	0.4045	0.4954	1.3452	0.6996	0.7509	0.4954	0.4954	1.0222	0.6996	1.1240	0.5938	0.6900
22	0.1228	0.4490	0.4954	0.8358	0.7509	2.8341	0.4954	0.4045	0.7509	0.6996	0.7509	0.4045	0.7500
23	0.1228	0.4490	0.4490	3.6014	0.9262	3.2139	0.4954	0.4490	0.6996	0.4045	0.6996	2.0070	1.1300
24	0.0976	0.4490	0.9262	2.8341	0.6458	2.3173	0.4954	0.4490	0.6996	0.5437	0.5437	1.0222	0.9200
25	0.1504	0.4954	1.8618	5.1775	0.5938	1.2316	0.4954	0.4045	0.5938	0.4954	0.5437	0.7509	1.0700
26	0.1504	0.4954	0.4045	2.3173	0.4954	1.1240	0.4045	0.3620	0.5437	0.4954	0.5437	0.6458	0.6700
27	0.1504	0.4954	0.2466	2.8341	0.4954	0.9262	0.4045	0.2830	0.4954	0.4045	0.4954	0.4954	0.6400
28	0.1504	0.4954	0.2123	2.0070	0.4954	1.2316	0.4045	0.2830	0.5437	0.4490	0.4954	0.4490	0.6000
29	0.1802		0.1504	0.9262	0.4490	0.9262	0.4490	1.2316	0.4954	0.4954	0.4954	0.3620	0.5600
30	0.1802		0.1504	2.8341	0.4490	1.3452	0.4045	0.4954	0.4954	0.6996	0.9262	0.4045	0.7600
31	0.1504		0.1504		0.4490		0.5938	1.3452		0.6458		0.3215	0.5200
MIN.	0.0976	0.0749	0.1504	0.0547	0.4490	0.4954	0.4045	0.2830	0.3620	0.2466	0.2830	0.2466	
MAX.	0.4954	0.4954	1.8618	7.1831	3.2139	3.2139	1.2316	1.3452	2.8341	0.6996	2.8341	2.4826	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B (B5) Daily Flow Data for Kibos River

YEAR : ***1954***

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	0.2466	0.5938	1.2316	0.5437	1.3452	3.0204	1.8618	1.3452	0.8358	1.8618	0.4954	1.1240	1.2100
2	0.2123	0.5437	0.5938	0.6996	6.6087	2.4826	1.1240	1.1240	0.7509	0.8358	0.4954	1.2316	1.3900
3	0.2123	0.5437	0.5938	0.8358	4.6794	2.3173	1.4650	4.0487	0.6996	0.7509	0.4490	0.5437	1.4300
4	0.1802	0.4954	0.5938	0.2830	2.3173	3.4148	1.4650	2.1588	0.6996	0.7509	0.4045	0.4045	1.1000
5	0.1802	0.4954	0.4954	4.3592	1.4650	2.8341	1.0222	1.4650	0.6996	0.7509	0.4954	0.3620	1.2200
6	0.1504	0.4954	0.4954	0.7509	1.1240	2.6548	0.9262	1.3452	0.6458	0.7509	0.3620	0.3215	0.8400
7	0.1504	0.4954	0.4954	0.4954	0.8358	1.8618	0.8358	1.2316	0.7509	0.5938	0.3620	0.6996	0.7300
8	0.1504	0.4954	0.5437	0.6996	1.1240	2.6548	0.8358	1.1240	0.7509	0.5938	0.3620	0.5437	0.8200
9	0.1504	0.4490	0.6996	0.4045	1.1240	3.2139	0.7509	1.1240	0.8358	0.5938	0.5437	0.8358	0.8900
10	0.1228	0.4490	0.6996	0.5938	4.0487	5.5214	0.9262	1.0222	1.3452	0.5938	0.4490	0.4954	1.3600
11	0.1228	0.4490	0.5938	0.8358	2.4826	3.8971	0.7509	0.9262	1.7232	0.5938	0.3620	0.3620	1.0900
12	0.0976	0.4490	0.4954	1.5909	1.7232	2.8341	1.1240	0.9262	1.4650	0.4954	0.3620	0.2830	0.9900
13	0.0976	0.4490	0.4954	0.9262	2.1588	2.6548	0.7509	1.1240	1.3452	0.5437	0.3215	0.2830	0.9300
14	0.0749	0.4490	0.4490	2.1588	1.5909	2.4826	0.7509	0.8358	1.1240	0.5938	0.3215	0.4045	0.9400
15	0.0976	0.4490	0.4490	1.1240	1.4650	1.7232	0.7509	1.1240	0.8358	0.6996	0.2830	0.4490	0.7900
16	0.5437	0.4490	0.4490	0.6458	4.0487	1.5909	1.1240	1.8618	0.7509	0.5938	0.2830	0.3620	1.0600
17	1.7232	0.4490	0.4490	0.6458	2.4826	2.8341	1.4650	1.2316	0.7509	0.5938	0.2830	0.4490	1.1100
18	0.6996	0.4045	0.4490	0.7509	2.1588	1.3452	0.8358	1.1240	0.6996	0.5437	0.2466	0.3620	0.8000
19	2.0070	0.4045	0.4490	0.6996	1.8618	1.2316	0.6996	0.8358	1.1240	0.4954	0.6996	0.2830	0.9000
20	0.4490	0.4045	0.4045	0.5437	1.4650	1.1240	0.6996	0.8358	0.6458	0.4954	0.6996	0.2466	0.6700
21	0.7509	0.4954	0.4045	0.4954	1.4650	1.0222	0.6996	1.0222	0.7509	0.5437	0.6458	0.2466	0.7100
22	0.3620	0.5437	0.4045	0.4490	1.3452	0.9262	0.6458	1.1240	0.7509	0.4954	0.6458	0.3620	0.6700
23	0.3215	0.4490	0.3620	0.3215	1.1240	0.8358	0.5938	2.3173	0.6996	0.4954	0.6996	0.2466	0.7100
24	0.2466	0.4490	0.3620	0.2123	1.1240	0.7509	0.5938	1.2316	0.5938	0.4045	0.6996	0.2466	0.5800
25	0.1802	0.5938	0.3620	0.2466	2.0070	0.7509	2.3173	1.2316	1.4650	0.5938	0.5938	0.2123	0.8800
26	0.1504	0.5938	0.3620	0.2466	1.2316	0.7509	1.8618	1.1240	0.8358	0.5938	0.5938	0.1802	0.7100
27	0.5938	0.5437	0.4490	0.6996	2.6548	0.9262	1.0222	0.9262	0.9262	0.5437	0.5938	0.4045	0.8600
28	0.5437	0.7509	0.4045	0.7509	2.3173	1.4650	1.1240	0.9262	1.3452	0.8358	0.5938	0.2466	0.9400
29	0.5938		0.4045	0.4954	1.4650	1.1240	0.8358	1.4650	0.8358	0.5938	0.6996	2.0070	0.9600
30	0.7509		0.4045	0.4490	2.6548	0.7509	2.6548	0.9262	0.9262	0.5437	0.9262	0.4954	1.0400
31	0.5938		0.4045		1.7232		1.7232	0.8358		0.5437		1.1240	0.9900
MIN.	0.0749	0.4045	0.3620	0.2123	0.8358	0.7509	0.5938	0.8358	0.5938	0.4045	0.2466	0.1802	
MAX.	2.0070	0.7509	1.2316	4.3592	6.6087	5.5214	2.6548	4.0487	1.7232	1.8618	0.9262	2.0070	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B (B6) Daily Flow Data for Kibos River

YEAR : **_1955_**

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	0.5437	0.8358	0.4490	0.6458	4.0487	1.1240	1.4650	1.4650	2.3173	5.5214	1.1240	0.7509	1.6900
2	0.4954	0.7509	0.3620	0.5938	2.4826	1.1240	1.4650	2.0070	4.5181	6.0547	1.1240	0.8358	1.8200
3	0.3215	0.7509	0.2830	0.5437	1.8618	2.8341	1.4650	1.2316	9.6802	5.3483	1.0222	0.7509	2.1700
4	0.3215	1.3452	0.2466	0.5437	5.5214	1.4650	2.0070	1.4650	5.5214	5.1775	1.0222	0.6458	2.1100
5	0.2466	1.3452	0.2466	0.4954	4.5181	2.4826	2.0070	1.1240	5.5214	6.0547	1.1240	0.6458	2.1500
6	0.2123	0.4490	0.6996	0.4954	4.0487	1.4650	1.4650	1.1240	5.0091	4.5181	1.1240	0.6458	1.7700
7	0.1802	0.6458	0.6996	0.4954	4.0487	1.1240	1.8618	1.1240	3.8971	4.0487	1.1240	0.6458	1.6600
8	0.5938	0.7509	0.6996	0.4954	6.0547	1.1240	1.8618	1.1240	3.2139	3.8971	3.0204	0.4954	1.9400
9	0.5938	3.0204	0.6458	0.7509	4.5181	1.1240	1.2316	1.1240	2.8341	3.4148	2.4826	0.5938	1.8600
10	0.5938	0.8358	0.6458	1.5909	3.6014	0.9262	1.1240	1.0222	2.4826	3.0204	1.4650	0.5938	1.4900
11	0.5437	0.5938	0.5938	3.0204	7.1831	0.8358	1.1240	1.2316	2.0070	3.6014	1.4650	0.5938	1.9000
12	0.5437	0.5437	0.5938	2.0070	11.0453	0.8358	1.1240	0.9262	1.5909	2.8341	1.2316	0.6458	1.9900
13	0.5938	0.4954	0.5938	2.0070	7.7777	0.7509	0.8358	0.9262	1.4650	2.4826	1.1240	3.0204	1.8400
14	0.5938	1.1240	0.5938	0.8358	5.0091	0.7509	3.0204	0.9262	2.4826	2.8341	1.1240	1.1240	1.7000
15	0.4954	0.5437	0.6458	2.0070	4.0487	0.6996	1.4650	1.1240	1.4650	2.8341	1.1240	5.5214	1.8300
16	0.4954	0.4490	0.6996	1.4650	3.0204	0.6996	1.1240	1.1240	1.7232	2.3173	1.2316	3.0204	1.4500
17	0.5938	0.4045	0.5938	0.9262	3.4148	0.6996	1.1240	1.0222	5.0091	2.0070	1.1240	4.0487	1.7500
18	0.5437	0.3215	0.5938	0.6996	3.0204	1.2316	3.0204	0.9262	3.0204	2.0070	0.9262	2.0070	1.5300
19	0.9262	0.2830	0.5437	0.5938	2.3173	0.6996	1.4650	0.8358	2.3173	2.0070	0.9262	2.1588	1.2600
20	0.6996	0.2466	0.4954	0.4954	2.3173	0.6458	1.3452	2.4826	3.0204	1.8618	0.9262	5.0091	1.6300
21	0.6458	0.2466	0.4954	0.4954	1.4650	0.6458	2.0070	2.0070	2.0070	1.5909	0.8358	3.0204	1.2900
22	0.5938	0.8358	0.4954	0.4490	2.0070	0.6458	4.0487	4.6794	4.3592	1.4650	1.0222	2.1588	1.9000
23	0.5938	2.1588	0.4954	0.4490	2.4826	0.9262	2.3173	2.8341	2.4826	1.4650	0.8358	1.8618	1.5800
24	0.5938	1.1240	0.5437	0.4490	1.4650	0.8358	2.8341	2.0070	3.6014	1.4650	0.8358	2.0070	1.4800
25	0.5437	0.6458	0.5938	2.0070	1.4650	0.6458	2.0070	1.5909	2.4826	1.3452	0.7509	2.0070	1.3400
26	0.5437	0.5938	0.8358	1.3452	1.1240	0.6996	4.0487	1.4650	2.0070	1.1240	0.7509	2.4826	1.4200
27	0.5437	0.5938	0.5938	3.4148	1.1240	1.2316	2.8341	4.0487	1.8618	1.1240	0.7509	1.4650	1.6300
28	2.0070	0.4954	0.5938	2.6548	1.1240	0.9262	2.3173	1.8618	2.0070	1.4650	0.6458	1.3452	1.4500
29	0.9262		1.1240	1.4650	1.1240	0.8358	1.8618	1.7232	3.6014	1.1240	1.3452	1.3452	1.5000
30	0.6996		0.8358	2.0070	1.1240	0.8358	1.5909	2.0070	3.6014	1.1240	0.8358	1.2316	1.4400
31	0.8358		0.7509		1.1240		1.4650	1.4650		1.1240		1.4650	1.1800
MIN.	0.1802	0.2466	0.2466	0.4490	1.1240	0.6458	0.8358	0.8358	1.4650	1.1240	0.6458	0.4954	
MAX.	2.0070	3.0204	1.1240	3.4148	11.0453	2.8341	4.0487	4.6794	9.6802	6.0547	3.0204	5.5214	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B Page 6 of 24

APPENDIX B (B7) Daily Flow Data for Kibos River

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	3.4148	1.0222	0.6458	0.9262	1.4650	2.1588	3.2139	0.8358	3.0204	2.4826	2.8341	0.6458	1.8900
2	1.4650	1.0222	0.6458	2.3173	3.8971	2.4826	3.2139	0.8358	2.3173	6.0547	1.5909	1.1240	2.2500
3	3.6014	0.9262	0.6458	1.8618	2.3173	2.0070	2.6548	0.8358	2.0070	7.1831	1.7232	1.1240	2.2400
4	2.4826	0.9262	0.5938	1.1240	2.4826	2.6548	2.1588	0.8358	1.5909	4.6794	2.0070	0.8358	1.8600
5	2.1588	0.8358	0.5437	1.0222	3.2139	2.3173	1.8618	0.7509	1.7232	4.2027	1.5909	0.8358	1.7500
6	2.1588	0.7509	0.5938	0.8358	1.8618	2.0070	1.7232	0.8358	1.1240	3.8971	1.4650	1.1240	1.5300
7	1.5909	0.7509	0.7509	0.7509	4.0487	1.7232	1.4650	0.7509	2.6548	3.6014	1.2316	0.8358	1.6800
8	1.7232	0.7509	0.6458	0.6458	3.6014	1.5909	1.4650	0.7509	1.8618	3.0204	1.1240	0.6458	1.4900
9	1.4650	0.6996	0.5938	0.6458	3.0204	1.4650	1.4650	0.7509	4.5181	2.4826	1.1240	0.6458	1.5700
10	1.2316	0.6996	0.4954	0.7509	2.8341	1.3452	1.3452	0.6996	3.2139	2.1588	1.1240	0.5938	1.3700
11	1.1240	0.6458	0.4954	0.8358	3.7480	1.3452	1.3452	0.6996	2.4826	2.0070	1.1240	0.5938	1.3700
12	1.1240	0.6458	0.4954	1.1240	2.3173	1.2316	1.1240	0.7509	2.0070	2.6548	1.1240	0.5938	1.2700
13	0.9262	0.6458	0.4954	0.6996	2.0070	1.1240	1.0222	1.1240	1.8618	2.0070	1.0222	0.5938	1.1300
14	0.8358	0.6458	0.4490	0.9262	4.6794	1.1240	1.0222	1.3452	3.4148	1.7232	1.0222	0.5437	1.4800
15	0.8358	0.6458	0.4490	2.1588	3.6014	1.1240	1.0222	1.1240	2.0070	1.4650	0.8358	0.4954	1.3100
16	0.9262	0.6996	0.4045	1.9410	3.0204	1.0222	1.0222	0.9262	2.0070	1.3452	0.9262	0.4954	1.2300
17	1.7232	2.4826	0.4490	1.7232	2.6548	1.0222	1.0222	0.8358	1.5909	1.4650	0.8358	0.4954	1.3600
18	0.5437	1.1240	0.4045	1.1240	2.1588	1.0222	1.0222	0.7509	1.4650	1.4650	0.8358	0.6458	1.0500
19	1.1240	4.0487	0.3620	1.0222	2.0070	1.0222	0.9262	0.7509	1.3452	1.1240	0.7509	0.5938	1.2600
20	1.4650	2.4826	0.3620	0.9262	2.1588	1.1240	0.9262	1.3452	1.2316	1.3452	0.7509	0.4954	1.2200
21	1.3452	1.7232	0.8358	3.0204	1.7232	1.0222	1.4650	0.8358	1.2316	1.4650	0.7509	0.4954	1.3300
22	2.0070	1.3452	0.5437	1.4650	1.7232	1.4650	1.1240	0.8358	1.1240	1.2316	0.6996	0.4954	1.1700
23	2.0070	1.1240	1.1240	1.3452	1.4650	1.1240	1.7232	1.4650	1.1240	1.3452	0.6996	0.4490	1.2500
24	1.4650	1.0222	0.8358	1.1240	1.7232	2.1588	1.1240	1.8618	1.2316	1.3452	0.6458	0.4490	1.2500
25	1.8618	0.9262	0.5938	2.1588	1.8618	1.2316	1.1240	5.0091	3.7480	3.6014	0.6458	0.4490	1.9300
26	1.8618	0.8358	0.5437	3.6014	3.0204	1.0222	1.3452	2.0070	1.8618	3.6014	0.6458	0.4490	1.7300
27	1.4650	0.7509	1.3452	3.0204	1.5909	1.1240	1.1240	1.3452	1.3452	1.5909	0.6458	0.5938	1.3300
28	1.4650	0.7509	0.6996	4.2027	2.8341	6.0547	1.0222	1.4650	2.0070	1.5909	0.5938	0.4954	1.9300
29	1.3452	0.6996	0.7509	2.4826	2.4826	5.3483	0.9262	2.6548	3.6014	1.3452	0.5938	0.4490	1.8900
30	1.2316		1.4650	1.8618	3.0204	3.6014	0.8358	1.3452	1.5909	1.2316	0.5938	0.4490	1.5700
31	1.4650		2.4826		2.6548		0.8358	5.0091		1.4650		0.6458	2.0800
MIN.	0.5437	1.0900	0.7000	1.5900	2.6200	1.8400	1.4100	1.3300	2.0800	2.4600	1.0500	0.6300	
MAX.	3.6014	4.0487	2.4826	4.2027	4.6794	6.0547	3.2139	5.0091	4.5181	7.1831	2.8341	1.1240	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B (B8) Daily Flow Data for Kibos River

YEAR : ***1957***

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	1.4650	0.6458	1.1240	1.8618	1.0222	3.4148	2.3173	1.3452	2.1588	1.1240	0.5938	0.4954	1.4600
2	0.5938	0.4954	1.2316	0.8358	13.2341	3.2139	2.1588	1.1240	2.6548	0.7509	0.7509	0.8358	2.3200
3	0.4954	0.4954	0.9262	0.5938	10.3532	3.0204	1.7232	1.4650	2.0070	0.7509	0.7509	4.3592	2.2500
4	0.4954	0.4490	0.8358	0.7509	6.9894	3.0204	1.4650	1.1240	1.4650	1.3452	0.5938	1.2316	1.6500
5	0.4490	0.4045	0.7509	0.5437	5.8746	2.8341	1.4650	1.3452	1.4650	0.8358	0.8358	0.8358	1.4700
6	2.0070	0.3620	0.7509	0.4954	4.5181	2.4826	2.0070	2.0070	1.3452	0.6996	2.0070	0.7509	1.6200
7	1.3452	0.3620	0.7509	0.5938	3.6014	3.0204	2.8341	1.1240	1.3452	0.6996	0.7509	0.8358	1.4400
8	0.5938	0.3620	0.7509	0.6458	4.0487	2.8341	3.4148	6.7979	1.1240	0.6458	0.6458	0.6996	1.8800
9	0.5437	0.3215	0.7509	1.5909	4.5181	2.6548	2.0070	3.0204	1.3452	0.6458	0.5938	0.6458	1.5500
10	0.4954	0.5938	0.6996	0.5938	4.0487	2.4826	1.8618	2.3173	1.1240	0.6458	1.1240	0.6458	1.3900
11	0.4954	0.6458	0.6996	0.5437	3.0204	1.8618	1.4650	1.7232	1.0222	0.5938	1.8618	0.6458	1.2100
12	0.4490	0.5938	1.4650	0.8358	3.0204	1.7232	1.5909	1.5909	1.4650	0.5938	1.0222	0.5938	1.2500
13	0.4490	0.4045	0.4045	0.8358	2.1588	1.5909	2.4826	1.7232	1.7232	0.5938	2.1588	0.5938	1.2600
14	0.4490	0.3215	0.3215	2.3173	2.4826	2.0070	1.7232	1.7232	1.1240	0.5938	1.1240	0.5938	1.2300
15	0.3620	0.2830	0.4045	2.0070	2.0070	1.7232	1.4650	1.3452	1.1240	0.5938	0.7509	0.4954	1.0500
16	0.3620	0.2466	0.2830	0.8358	2.0070	2.0070	1.3452	1.1240	1.4650	0.5437	0.6996	0.4954	0.9500
17	0.3620	0.2466	0.2466	0.6996	2.6548	2.6548	1.3452	1.3452	1.4650	0.5938	0.6458	0.4954	1.0600
18	0.3620	0.6458	0.2123	0.6458	3.6014	1.7232	1.2316	1.4650	2.4826	0.7509	0.6458	0.4954	1.1900
19	0.3215	0.6458	0.6458	0.5437	3.2139	1.4650	1.1240	1.4650	1.7232	0.5938	0.6458	0.4954	1.0700
20	0.3620	0.6458	0.6458	1.4650	3.6014	1.8618	1.1240	1.0222	1.1240	0.5437	0.5938	0.4490	1.1200
21	0.3620	0.8358	0.5938	3.8971	3.0204	1.5909	1.0222	1.0222	1.3452	0.5938	0.5938	0.5938	1.2900
22	0.4045	0.9262	0.7509	1.8618	3.0204	2.0070	1.0222	0.9262	1.0222	0.5938	0.5437	0.4954	1.1300
23	0.6458	0.8358	0.6458	1.2316	2.6548	1.4650	0.9262	0.8358	0.9262	4.0487	0.5938	0.7509	1.3000
24	0.4954	2.4826	0.6458	1.1240	4.0487	4.0487	0.9262	1.0222	0.8358	0.9262	0.6458	0.7509	1.5000
25	0.4045	0.8358	0.6458	1.1240	3.2139	2.4826	1.5909	0.8358	0.8358	1.1240	0.5938	0.4954	1.1800
26	0.4045	0.7509	0.6458	2.0070	3.8971	2.1588	1.1240	1.8618	0.7509	0.7509	0.5437	0.4490	1.2800
27	0.4045	0.7509	0.6458	1.7232	3.8971	4.5181	1.2316	5.6968	0.7509	0.6996	0.4954	0.4490	1.7700
28	0.3620	0.7509	0.6996	1.1240	3.0204	2.4826	1.8618	2.4826	0.7509	0.6458	0.5938	0.8358	1.3000
29	0.4490		1.1240	0.9262	2.6548	2.4826	2.6548	2.3173	0.7509	1.4650	0.6458	0.6458	1.4700
30	0.6996		0.8358	0.9262	5.1775	2.0070	1.4650	1.5909	0.7509	0.7509	0.4954	0.7509	1.4000
31	0.5437		0.6996		4.0487		1.4650	3.6014		0.6458		0.6458	1.6600
MIN.	0.3215	0.2466	0.2123	0.4954	1.0222	1.4650	0.9262	0.8358	0.7509	0.5437	0.4954	0.4490	
MAX.	2.0070	2.4826	1.4650	3.8971	13.2341	4.5181	3.4148	6.7979	2.6548	4.0487	2.1588	4.3592	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B (B9) Daily Flow Data for Kibos River

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	2.8341	0.6996	0.5938	0.6996	1.7232	0.6458	0.8358	1.1240	0.9262	0.5437	0.4954	0.4045	0.9600
2	0.8358	0.6458	0.5938	0.6458	0.8358	1.3452	0.8358	1.4650	0.8358	0.4954	0.4954	0.4490	0.7900
3	0.6996	0.6458	0.5938	0.6458	2.0070	0.8358	0.7509	1.1240	2.0070	0.6458	0.4954	0.3620	0.9000
4	0.5938	0.6458	0.5938	0.5938	1.1240	1.0222	0.7509	1.0222	1.1240	0.6458	0.6458	0.3620	0.7600
5	0.5938	0.5938	0.5437	0.6458	0.8358	1.4650	0.8358	0.8358	0.9262	1.3452	0.4954	0.3620	0.7900
6	0.4954	1.0222	0.5437	0.6458	1.2316	1.3452	1.1240	0.8358	0.8358	0.6996	0.4954	0.2830	0.8000
7	0.4954	0.8358	0.5938	0.6458	0.8358	1.0222	0.7509	0.8358	1.3452	0.6458	0.4954	0.6996	0.7700
8	0.4490	1.7232	0.6458	0.6996	0.6458	1.0222	0.8358	0.7509	1.1240	1.3452	0.4490	0.6996	0.8700
9	0.4045	1.0222	0.6996	1.1240	0.8358	1.2316	0.6458	1.5909	0.9262	0.7509	0.4045	0.6996	0.8600
10	0.4045	0.9262	0.6458	0.7509	0.5938	0.9262	0.6458	1.1240	1.1240	3.4148	0.4490	0.6996	0.9800
11	0.4045	1.4650	0.6458	0.7509	0.6458	0.7509	0.5938	0.8358	0.8358	1.4650	0.4954	0.6458	0.7900
12	0.4045	1.7232	0.5938	0.6996	1.1240	0.6996	0.5938	1.0222	0.7509	1.1240	0.4954	0.6996	0.8300
13	0.3620	1.1240	0.5938	0.6458	1.4650	0.9262	2.6548	3.6014	0.7509	1.1240	0.5437	0.8358	1.2200
14	0.3215	0.4954	0.5938	0.6458	1.1240	0.6458	6.7979	2.0070	0.7509	0.8358	0.5437	0.7509	1.2900
15	0.2830	0.4954	0.5938	0.6458	0.8358	0.6458	9.6802	1.5909	0.7509	0.6996	0.4954	0.8358	1.4600
16	0.2830	1.0222	0.5938	0.7509	1.1240	0.9262	5.5214	4.5181	0.6996	0.8358	0.4954	1.0222	1.4800
17	0.2466	0.5437	1.5909	1.1240	0.7509	0.5938	4.6794	2.3173	0.7509	0.6458	0.4490	1.1240	1.2300
18	0.2466	0.4490	2.0070	0.4490	0.6458	0.5437	3.6014	3.0204	0.6458	0.6458	0.6996	2.4826	1.2900
19	0.6458	0.4045	1.1240	0.3215	0.5938	1.3452	3.0204	2.6548	0.6458	0.5938	0.4954	1.1240	1.0800
20	0.6996	0.3620	0.9262	0.2466	0.5437	0.8358	2.3173	2.1588	0.5938	0.5938	0.4490	2.0070	0.9800
21	0.6996	0.2830	0.8358	0.2466	0.5437	0.6458	2.0070	1.7232	0.5938	0.5437	0.4045	4.3592	1.0700
22	0.6996	0.2466	0.7509	0.4954	0.8358	0.6458	1.5909	1.4650	0.5938	0.5938	0.3620	3.8971	1.0100
23	0.7509	0.2466	0.7509	0.3620	1.0222	0.5938	1.4650	1.3452	0.5938	1.1240	0.3620	5.5214	1.1800
24	0.7509	0.2123	0.6996	0.4490	0.6458	0.5437	1.3452	1.4650	0.6458	0.6458	0.4045	2.8341	0.8900
25	0.8358	0.6458	0.6458	0.9262	0.5437	2.1588	1.1240	1.4650	0.5938	0.5938	1.0222	2.0070	1.0500
26	0.7509	0.6458	0.6458	0.5437	0.5437	1.7232	1.0222	1.3452	0.5938	0.7509	1.3452	1.8618	0.9800
27	0.8358	0.6458	0.9262	0.4045	0.5938	1.5909	1.0222	1.4650	0.5938	0.5437	0.4954	1.5909	0.8900
28	0.7509	0.5938	2.4826	0.4045	0.5938	1.4650	2.3173	1.2316	0.6458	0.5938	0.5437	1.3452	1.0800
29	0.7509		1.0222	0.8358	1.1240	1.1240	2.4826	1.1240	0.6458	0.5938	0.4954	1.2316	1.0400
30	0.6996		0.8358	0.4954	0.5938	0.9262	1.8618	1.0222	0.5938	0.5437	0.4490	1.1240	0.8300
31	0.6996		0.7509		0.5437		1.4650	0.9262		0.4954		1.1240	0.8600
MIN.	0.2466	0.2123	0.5437	0.2466	0.5437	0.5437	0.5938	0.7509	0.5938	0.4954	0.3620	0.2830	
MAX.	2.8341	1.7232	2.4826	1.1240	2.0070	2.1588	9.6802	4.5181	2.0070	3.4148	1.3452	5.5214	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B (B10) Daily Flow Data for Kibos River

YEAR : ***1959***

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	1.0222	0.6458	2.3173	1.0222	1.3452	0.8358	0.5437	0.4490	0.4954	0.7509	1.2316	2.0070	1.0600
2	1.0222	0.6458	4.3592	1.0222	1.3452	1.1240	0.5938	0.4954	0.6996	0.8358	1.7232	2.6548	1.3800
3	0.8358	0.6458	2.0070	0.9262	0.8358	1.8618	0.5938	0.9262	0.5938	1.3452	13.2341	1.7232	2.1300
4	0.8358	0.6458	1.4650	0.8358	5.8746	0.9262	0.5938	0.4954	0.4954	1.0222	6.2371	1.3452	1.7300
5	0.8358	0.6458	0.7509	0.7509	3.6014	0.8358	0.5938	0.5938	0.5437	4.2027	11.0453	1.1240	2.1300
6	0.8358	0.5938	0.5938	0.7509	1.4650	1.1240	0.7509	1.2316	1.1240	3.2139	6.6087	1.1240	1.6200
7	0.7509	0.5938	0.4954	0.7509	1.0222	0.7509	0.5938	0.6996	0.5938	1.4650	6.0547	1.0222	1.2300
8	0.7509	4.5181	0.6996	0.6996	0.8358	0.7509	0.5437	0.6996	1.1240	3.6014	5.0091	1.0222	1.6900
9	0.7509	1.1240	1.0222	0.6996	0.8358	0.6458	0.5938	0.4954	0.6458	2.6548	4.0487	0.8358	1.2000
10	1.0222	1.7232	0.5938	0.7509	1.1240	0.6458	0.4954	0.4954	0.5938	1.4650	3.6014	0.8358	1.1100
11	0.9262	0.4045	0.4954	0.7509	0.7509	0.6458	0.4954	0.4045	1.0222	1.8618	3.0204	1.3452	1.0100
12	0.8358	0.3215	0.4045	0.7509	1.4650	0.7509	0.4490	0.4045	0.6458	1.3452	2.4826	1.4650	0.9400
13	0.8358	0.2830	0.3620	1.0222	0.8358	0.6458	0.4490	0.4045	0.6996	1.1240	2.1588	0.9262	0.8100
14	0.7509	0.4954	0.2830	0.9262	3.7480	0.6458	0.4490	0.3620	1.7232	1.1240	2.0070	0.8358	1.1100
15	0.7509	0.4490	0.2830	1.4650	1.7232	0.7509	0.4045	0.4045	0.6996	1.1240	1.7232	0.8358	0.8800
16	0.7509	0.2830	0.2466	0.8358	1.3452	0.6458	0.4045	0.4490	0.6996	0.8358	1.4650	0.7509	0.7300
17	0.7509	0.2466	0.2466	0.9262	1.7232	0.5938	0.4045	1.1240	0.6458	0.7509	1.3452	0.7509	0.7900
18	0.6996	0.2123	0.1802	2.6548	2.4826	0.5938	0.4045	1.2316	0.5938	0.7509	1.3452	0.9262	1.0100
19	0.6996	0.1802	0.6458	1.4650	1.3452	0.5938	0.4045	0.5437	0.6458	3.0204	1.1240	0.7509	0.9500
20	0.6996	0.6458	0.8358	2.0070	4.3592	0.8358	0.4045	0.5437	0.7509	1.1240	1.2316	0.6996	1.1800
21	0.6458	0.6458	0.8358	1.3452	2.0070	0.7509	0.4045	0.4954	1.1240	0.8358	1.2316	0.6458	0.9100
22	0.6996	0.6458	1.4650	3.6014	4.0487	0.5938	0.4045	0.4954	1.5909	0.8358	1.2316	0.6458	1.3500
23	0.6458	1.1240	0.9262	1.0222	5.3483	0.5938	0.4045	0.4490	0.6996	0.9262	1.1240	0.6458	1.1600
24	0.8358	0.6996	0.7509	1.4650	3.6014	0.5437	0.4045	0.4954	0.5938	3.6014	1.1240	0.6458	1.2300
25	0.8358	0.6458	1.4650	1.0222	2.4826	0.4954	0.4045	4.6794	1.1240	3.0204	1.1240	0.5938	1.4900
26	0.8358	1.1240	4.5181	0.8358	2.0070	0.5437	0.3620	1.0222	1.0222	1.8618	0.9262	0.5938	1.3000
27	1.0222	0.8358	1.7232	0.9262	1.4650	0.5437	0.4045	0.6996	1.0222	1.7232	0.9262	0.5938	0.9900
28	0.7509	1.4650	3.6014	0.8358	1.3452	0.4954	0.3620	0.6458	1.2316	1.2316	1.0222	0.8358	1.1500
29	0.6996		1.5909	0.7509	1.2316	0.4954	0.3620	0.6458	1.2316	1.4650	3.6014	1.1240	1.2000
30	0.6458		1.3452	1.1240	1.0222	0.7509	0.3620	0.7509	0.7509	1.2316	1.8618	0.7509	0.9600
31	0.6458		1.1240		0.9262		0.9262	0.5938		1.7232		0.6458	0.9400
MIN.	0.6458	0.1802	0.1802	0.6996	0.7509	0.4954	0.3620	0.3620	0.4954	0.7509	0.9262	0.5938	
MAX.	1.0222	4.5181	4.5181	3.6014	5.8746	1.8618	0.9262	4.6794	1.7232	4.2027	13.2341	2.6548	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B (B11) Daily Flow Data for Kibos River

YEAR : **1960**

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	0.5938	0.4045	0.9262	4.5181	4.0487	3.0204	1.3452	0.8358	0.8358	2.0070	0.6458	0.6458	1.6500
2	1.3452	0.6458	0.9262	5.0091	4.2027	2.6548	1.2316	0.8358	0.7509	3.6014	1.1240	0.6458	1.9100
3	0.6458	0.5437	1.1240	4.0487	3.4148	2.3173	1.1240	0.7509	1.3452	3.0204	0.9262	0.6458	1.6600
4	0.5938	0.5938	1.4650	3.0204	3.0204	2.0070	1.5909	0.7509	0.8358	1.8618	0.8358	0.6458	1.4400
5	0.5938	0.4490	3.4148	3.0204	3.0204	1.8618	1.3452	0.7509	0.8358	1.4650	0.8358	0.5938	1.5200
6	0.5437	0.4045	1.4650	4.3592	2.4826	1.8618	1.2316	0.7509	1.0222	2.0070	0.8358	0.5437	1.4600
7	0.5437	0.3620	1.1240	4.0487	2.0070	2.4826	1.2316	0.7509	2.6548	1.4650	2.0070	0.5938	1.6100
8	0.4954	0.3620	1.0222	3.0204	1.7232	2.4826	1.4650	1.3452	1.1240	1.1240	0.8358	0.5437	1.3000
9	0.4954	0.2830	1.0222	2.1588	1.5909	2.0070	3.6014	0.7509	4.5181	1.1240	0.6458	0.5938	1.5700
10	0.6458	0.7509	1.0222	2.1588	1.4650	2.1588	2.0070	0.8358	2.1588	1.0222	0.6458	0.5437	1.2800
11	0.5938	0.7509	0.9262	2.3173	1.7232	1.7232	1.7232	1.8618	3.2139	1.0222	1.1240	0.4954	1.4600
12	0.5437	0.7509	0.9262	1.7232	1.5909	1.5909	1.7232	1.1240	1.7232	1.0222	1.7232	0.4954	1.2400
13	0.6458	0.7509	0.8358	1.5909	2.0070	2.6548	1.7232	0.8358	2.4826	1.2316	1.4650	0.4954	1.3900
14	0.6458	0.7509	0.8358	2.1588	1.7232	1.8618	1.7232	0.8358	1.4650	1.0222	0.9262	0.4954	1.2000
15	0.5437	1.4650	1.1240	2.4826	1.5909	1.7232	1.2316	0.8358	1.2316	0.9262	1.3452	0.4490	1.2500
16	0.4954	1.0222	1.0222	1.7232	1.4650	1.5909	1.1240	0.8358	1.1240	0.8358	1.3452	0.4954	1.0900
17	0.4954	1.1240	1.0222	2.3173	1.2316	1.4650	1.2316	0.7509	1.0222	0.7509	5.0091	0.4954	1.4100
18	0.4954	1.3452	2.1588	3.0204	1.3452	1.4650	1.1240	0.6458	1.0222	0.7509	3.0204	0.4954	1.4100
19	0.4954	2.4826	2.0070	1.4650	1.7232	1.3452	1.3452	0.7509	0.8358	0.8358	1.8618	0.6458	1.3200
20	0.4490	1.1240	1.3452	1.7232	1.4650	1.3452	1.4650	0.7509	0.8358	0.7509	1.4650	0.5437	1.1100
21	0.4490	0.9262	4.5181	1.4650	4.0487	1.2316	1.2316	0.7509	0.8358	0.7509	1.2316	1.1240	1.5500
22	0.4490	0.8358	1.3452	1.2316	3.6014	1.7232	1.1240	0.6458	1.0222	0.6996	1.1240	0.5938	1.2000
23	0.4954	0.8358	0.8358	1.3452	2.6548	1.4650	1.4650	1.3452	0.9262	0.6996	1.0222	0.5437	1.1400
24	0.4490	0.7509	2.4826	7.5773	4.6794	1.2316	1.1240	0.8358	1.1240	0.6458	1.1240	0.4954	1.8800
25	0.6458	0.7509	2.6548	4.2027	3.0204	1.2316	1.0222	1.3452	0.8358	0.6458	0.9262	0.5938	1.4900
26	0.5938	0.8358	1.5909	7.9804	3.6014	1.3452	0.9262	0.9262	0.8358	0.6458	0.8358	0.5437	1.7200
27	0.4954	0.8358	2.0070	4.6794	6.0547	3.6014	0.9262	0.8358	1.2316	0.6458	0.7509	0.4954	1.8800
28	0.4954	0.9262	4.3592	4.0487	3.7480	2.0070	0.8358	0.8358	0.8358	0.6458	0.7509	0.4490	1.6600
29	0.4490	0.9262	3.2139	4.5181	4.5181	1.5909	0.9262	0.7509	0.8358	0.6458	0.7509	0.4045	1.6300
30	0.4954		2.6548	3.6014	4.5181	1.4650	0.8358	0.8358	1.7232	0.7509	0.8358	0.4045	1.6500
31	0.4490		2.4826		3.6014		0.8358	1.0222		0.6458		0.4045	1.3500
MIN.	0.4490	0.2830	0.8358	1.2316	1.2316	1.2316	0.8358	0.6458	0.7509	0.6458	0.6458	0.4045	
MAX.	1.3452	2.4826	4.5181	7.9804	6.0547	3.6014	3.6014	1.8618	4.5181	3.6014	5.0091	1.1240	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B (B12) Daily Flow Data for Kibos River

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	0.4045	0.6458	0.6996	1.0222	0.4490	2.1588	0.5938	0.4045	1.1240	4.5181	6.6087	6.9894	2.1300
2	0.4045	0.6458	0.6458	0.8358	0.4490	2.0070	0.4954	0.4045	0.6458	5.0091	7.7777	6.9894	2.1900
3	0.3620	0.6458	1.2316	0.8358	3.0204	1.4650	0.4954	0.4045	0.4954	3.6014	6.6087	9.6802	2.4000
4	0.7509	0.6458	0.8358	0.9262	5.0091	1.1240	0.4954	0.4045	0.9262	6.6087	6.7979	7.7777	2.6900
5	0.7509	1.0222	0.6996	0.7509	1.8618	0.8358	0.6458	0.3620	1.3452	5.8746	5.6968	6.9894	2.2400
6	0.7509	0.7509	0.6458	0.7509	3.0204	0.7509	0.4954	0.4954	0.7509	4.0487	5.1775	7.1831	2.0700
7	0.7509	0.7509	0.6458	1.1240	2.6548	0.6996	0.4954	0.4490	0.6996	9.0265	4.0487	7.7777	2.4300
8	0.7509	0.7509	0.5938	3.6014	1.8618	0.7509	0.4490	0.4954	0.6458	5.0091	4.0487	7.7777	2.2300
9	0.7509	0.7509	0.5938	4.0487	1.3452	1.0222	0.8358	0.5938	0.6458	5.3483	6.7979	9.6802	2.7000
10	0.7509	0.6996	0.5938	2.1588	1.1240	0.6458	0.6458	0.4954	0.5437	3.6014	14.0008	9.6802	2.9100
11	0.7509	0.6996	0.5437	0.8358	1.3452	0.6458	0.5437	0.5437	0.4954	3.2139	13.2341	9.2422	2.6700
12	0.6996	0.6996	0.5938	0.6458	1.4650	0.6458	0.4954	0.4954	0.6458	3.0204	6.9894	9.6802	2.1700
13	0.6996	0.6996	0.5437	1.2316	1.4650	0.6458	0.4954	0.4954	0.5938	3.4148	6.7979	7.1831	2.0200
14	0.6996	0.7509	0.6458	0.7509	2.0070	0.5938	0.5437	0.4490	0.9262	2.6548	6.9894	13.2341	2.5200
15	0.6996	0.6996	0.6458	0.6996	1.4650	0.6458	0.9262	0.6996	0.8358	2.6548	6.9894	7.1831	2.0100
16	0.6458	0.6996	1.1240	0.4954	1.1240	1.1240	0.6458	0.5437	1.0222	1.8618	6.9894	6.9894	1.9400
17	0.6458	0.7509	1.0222	0.5437	0.9262	0.6458	0.5938	0.4954	0.6458	1.7232	9.6802	9.6802	2.2800
18	0.6458	1.1240	0.8358	0.5938	0.8358	0.6458	0.5437	0.5437	0.5437	1.4650	13.4876	9.6802	2.5800
19	0.6458	0.7509	0.7509	0.7509	0.7509	0.8358	0.5938	0.5938	1.3452	3.0204	13.4876	8.3923	2.6600
20	0.6996	0.6996	0.8358	0.4954	0.6996	0.6458	0.5938	0.5437	1.4650	1.4650	13.4876	7.1831	2.4000
21	0.6458	1.3452	1.7232	0.5437	1.3452	0.5938	0.4954	0.5437	1.1240	3.0204	13.2341	6.6087	2.6000
22	0.6458	0.7509	1.4650	0.5437	0.8358	0.5938	0.4954	0.4954	1.0222	2.8341	13.4876	7.1831	2.5300
23	0.6458	0.7509	0.9262	0.4490	0.6996	0.5437	0.4954	0.4490	0.8358	4.5181	6.9894	6.6087	1.9900
24	0.6996	0.6458	0.8358	0.4045	0.6996	0.4954	0.4954	0.4490	0.7509	4.5181	13.2341	6.6087	2.4900
25	0.7509	0.6458	0.7509	0.3620	0.6458	0.4954	0.5437	0.4490	1.1240	4.5181	6.9894	5.5214	1.9000
26	0.6996	0.6458	0.6996	0.3620	0.6458	0.5437	0.5437	0.4490	3.6014	9.6802	7.1831	9.6802	2.8900
27	0.6458	0.6458	0.7509	0.3215	1.0222	0.4954	0.4490	0.3620	4.0487	6.0547	14.0008	6.6087	2.9500
28	0.6458	0.8358	0.7509	0.3215	0.7509	0.4954	0.4954	0.4045	2.6548	4.6794	13.4876	6.0547	2.6300
29	0.6458		0.7509	0.4045	1.3452	0.5938	0.4490	0.3620	2.4826	4.0487	13.2341	9.2422	3.0500
30	0.6458		0.6996	0.4490	0.7509	0.5437	0.4490	0.4045	4.5181	4.8430	10.3532	7.1831	2.8000
31	0.6458		1.2316		1.1240		0.4490	0.5437		6.6087		9.6802	2.9000
MIN.	0.3620	0.6458	0.5437	0.3215	0.4490	0.4954	0.4490	0.3620	0.4954	1.4650	4.0487	5.5214	
MAX.	0.7509	1.3452	1.7232	4.0487	5.0091	2.1588	0.9262	0.6996	4.5181	9.6802	14.0008	13.2341	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B (B13) Daily Flow Data for Kibos River

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	9.6802	2.6548	1.3452	1.1240	3.8971	9.6802	4.5181	2.3173	2.4826	2.1588	3.6014	3.2139	3.8900
2	9.6802	2.4826	1.4650	1.1240	10.3532	6.6087	4.3592	3.0204	3.0204	1.8618	3.0204	2.6548	4.1400
3	9.6802	2.4826	4.3592	1.4650	8.3923	6.0547	4.0487	3.0204	2.4826	1.7232	3.0204	2.6548	4.1200
4	7.7777	2.3173	1.4650	1.1240	13.2341	5.8746	4.0487	4.3592	2.1588	1.5909	2.4826	2.4826	4.0800
5	6.9894	2.0070	1.3452	1.1240	12.4859	6.6087	3.6014	2.8341	2.0070	1.5909	2.4826	2.1588	3.7700
6	6.0547	1.4650	1.2316	3.0204	11.0453	5.8746	3.4148	2.4826	2.0070	2.0070	2.1588	2.0070	3.5600
7	5.8746	1.2316	1.5909	2.1588	9.6802	5.3483	4.0487	2.1588	2.0070	2.0070	3.0204	2.0070	3.4300
8	6.0547	2.1588	1.3452	2.4826	9.0265	5.3483	3.8971	2.0070	2.1588	3.2139	2.4826	2.0070	3.5200
9	6.4217	2.1588	1.2316	2.0070	13.2341	5.0091	3.6014	2.0070	2.4826	2.0070	2.1588	3.0204	3.7800
10	9.6802	2.0070	1.1240	6.2371	6.6087	4.8430	3.4148	3.0204	2.0070	2.4826	2.0070	2.6548	3.8400
11	9.2422	1.8618	1.1240	4.5181	13.2341	4.6794	3.0204	4.0487	2.1588	2.3173	2.0070	2.0070	4.1800
12	6.6087	1.7232	4.0487	5.3483	6.7979	5.3483	3.0204	2.4826	2.0070	2.0070	1.8618	2.0070	3.6100
13	6.0547	1.5909	4.0487	5.5214	6.6087	4.6794	2.8341	2.3173	3.6014	3.0204	1.7232	1.5909	3.6300
14	5.5214	1.7232	1.4650	5.1775	12.4859	4.5181	2.8341	3.0204	2.8341	2.6548	1.5909	1.4650	3.7700
15	5.3483	1.5909	1.5909	8.3923	9.6802	4.0487	2.6548	2.4826	3.0204	2.0070	1.7232	1.4650	3.6700
16	5.0091	1.4650	1.0222	5.5214	10.3532	4.3592	2.4826	2.1588	3.7480	3.0279	1.8618	1.4650	3.5400
17	5.0091	1.3452	3.0204	4.5181	10.3532	4.8430	2.6548	2.8341	3.0204	3.0279	1.5909	1.4650	3.6400
18	5.0091	1.4650	1.7232	4.2027	6.6087	4.2027	3.8971	4.5181	4.0487	4.0487	1.4650	1.3452	3.5400
19	4.0487	1.3452	3.6014	3.8971	13.4876	4.5181	6.0547	5.5214	3.6014	3.2139	1.4650	1.3452	4.3400
20	4.2027	1.4650	1.8618	3.2139	14.0008	5.5214	3.8971	4.5181	3.0204	2.6548	1.4650	1.1240	3.9100
21	4.0487	1.3452	2.6548	2.8341	13.2341	5.0091	3.6014	3.8971	2.6548	4.0487	1.4650	1.1240	3.8300
22	4.0487	1.4650	4.8430	3.0204	11.0453	5.0091	3.0204	3.6014	2.4826	3.2139	1.4650	1.1240	3.6900
23	4.3592	1.4650	5.0091	6.2371	10.3532	4.8430	3.0204	3.0204	2.1588	3.0204	1.4650	1.1240	3.8400
24	5.5214	1.7232	2.6548	5.5214	9.4602	5.5214	3.0204	3.0204	2.1588	3.2139	1.3452	1.1240	3.6900
25	4.0487	1.4650	2.3173	4.5181	9.0265	5.3483	3.0204	2.6548	2.0070	2.6548	1.4650	0.8358	3.2800
26	3.8971	1.3452	1.4650	4.0487	9.4602	4.8430	2.6548	3.2139	2.1588	2.8341	3.6014	0.8358	3.3600
27	4.5181	1.3452	1.5909	3.8971	9.0265	4.5181	2.4826	3.4148	1.8618	3.6014	4.0487	1.1240	3.4500
28	3.8971	1.4650	1.4650	3.8971	7.1831	4.3592	2.3173	4.0487	1.8618	3.0204	1.7232	1.1240	3.0300
29	3.4148		1.3452	4.0487	7.1831	4.0487	2.3173	3.6014	2.3173	3.0204	2.1588	1.0222	3.1300
30	3.0204		1.3452	4.0487	6.6087	4.0487	2.1588	3.0204	3.6014	4.5181	5.5214	2.6548	3.6900
31	2.8341		1.2316		6.7979		2.0070	3.0204		4.0487		1.7232	3.0900
MIN.	2.8341	1.2316	1.0222	1.1240	3.8971	4.0487	2.0070	2.0070	1.8618	1.5909	1.3452	0.8358	
MAX.	9.6802	2.6548	5.0091	8.3923	14.0008	9.6802	6.0547	5.5214	4.0487	4.5181	5.5214	3.2139	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

YEAR : **1963**

APPENDIX B (B14) Daily Flow Data for Kibos River

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	1.3452	0.9262	0.8358	0.8358	7.1831	5.0091	3.2139	1.4650	1.4650	0.6996	0.8358	4.6794	2.3700
2	1.1240	0.8358	0.8358	1.4650	6.0547	4.8430	2.6548	1.4650	1.5909	0.7509	0.6996	3.6014	2.1600
3	1.1240	0.8358	0.9262	1.4650	7.1831	4.3592	2.3173	1.3452	1.7232	0.7509	0.6458	6.6087	2.4400
4	1.1240	0.8358	0.9262	1.0222	9.0265	4.0487	2.3173	1.2316	1.4650	0.6996	0.8358	6.0547	2.4700
5	1.4650	0.7509	1.4650	0.8358	9.2422	10.3532	2.3173	2.4826	1.4650	0.6458	0.8358	5.5214	3.1200
6	1.7232	0.7509	1.4650	0.8358	9.2422	5.5214	2.1588	1.4650	1.4650	0.6458	0.7509	4.5181	2.5500
7	4.3592	0.7509	1.4650	0.7509	7.7777	5.3483	3.6014	1.2316	1.1240	0.6458	0.6458	4.3592	2.6700
8	1.4650	1.0222	1.0222	0.6996	7.1831	4.8430	2.3173	1.1240	0.9262	1.4650	0.6458	5.5214	2.3500
9	4.2027	1.2316	0.9262	0.7509	9.0265	4.5181	2.1588	1.1240	0.8358	1.7232	0.6458	5.5214	2.7200
10	2.4826	4.0487	0.8358	0.6996	6.6087	4.3592	2.0070	1.0222	0.8358	1.4650	0.7509	5.8746	2.5800
11	2.0070	1.3452	0.8358	0.7509	6.6087	4.0487	2.0070	0.9262	0.8358	1.1240	0.5938	6.0547	2.2600
12	1.5909	2.3173	0.7509	0.6996	6.4217	4.5181	2.0070	1.4650	1.3452	0.7509	0.7509	5.6968	2.3600
13	1.7232	2.0070	0.7509	1.7232	6.6087	3.6014	2.0070	1.3452	1.3452	2.4826	1.1240	5.0091	2.4800
14	1.4650	2.0070	0.8358	2.1588	6.4217	3.4148	2.0070	1.7232	1.4650	0.7509	4.5181	4.5181	2.6100
15	1.5909	3.0204	0.9262	1.4650	1.7232	3.2139	2.0070	2.0070	0.8358	0.6996	2.0070	3.6014	1.9200
16	2.3173	3.0204	0.8358	5.5214	4.5181	3.2139	1.7232	1.4650	0.9262	0.6996	1.1240	3.6014	2.4100
17	2.0070	2.8341	4.5181	3.0204	4.5181	3.0204	1.5909	1.4650	1.7232	0.6458	1.4650	2.8341	2.4700
18	1.4650	2.0070	1.8618	8.3923	5.5214	3.0204	1.4650	1.4650	1.3452	0.6458	2.0070	2.4826	2.6400
19	1.3452	1.5909	1.3452	5.5214	4.8430	2.6548	1.5909	1.3452	1.3452	0.6458	2.8341	2.1588	2.2700
20	1.4650	1.3452	1.1240	4.5181	4.5181	3.0204	2.0070	1.1240	1.0222	0.6458	1.4650	2.3173	2.0500
21	1.5909	1.2316	1.0222	4.5181	4.0487	2.6548	1.8618	1.1240	0.8358	0.6458	1.4650	2.0070	1.9200
22	2.0070	1.1240	1.0222	4.5181	4.0487	2.4826	2.0070	0.0547	0.8358	0.5938	1.2316	2.6548	1.8800
23	2.0070	1.1240	0.8358	7.7777	6.0547	2.4826	1.7232	1.1240	0.8358	0.6458	1.1240	1.8618	2.3000
24	1.4650	1.1240	0.8358	8.3923	4.0487	2.4826	1.8618	1.1240	0.8358	0.5938	1.4650	1.3452	2.1300
25	1.3452	1.3452	0.8358	6.6087	5.5214	2.3173	1.5909	0.1504	0.7509	0.5938	2.0070	3.2139	2.1900
26	1.1240	1.1240	0.8358	9.2422	9.0265	3.2139	1.4650	1.4650	1.1240	0.6458	2.1588	2.3173	2.8100
27	1.1240	1.1240	0.8358	6.6087	6.0547	2.6548	1.4650	1.1240	0.8358	0.6996	2.4826	1.8618	2.2400
28	1.1240	1.1240	0.6996	15.0512	6.6087	3.0204	1.4650	1.1240	0.8358	0.7509	4.5181	2.4826	3.2300
29	1.1240		1.1240	11.7562	6.2371	3.2139	1.3452	1.1240	0.7509	0.7509	6.6087	2.0070	3.2800
30	1.0222		1.0222	7.7777	6.0547	3.0204	1.3452	1.7232	0.6996	0.6996	5.8746	1.5909	2.8000
31	1.0222		1.0222		5.5214		1.3452	1.7232		0.6458		1.7232	1.8600
MIN.	1.0222	0.7509	0.6996	0.6996	1.7232	2.3173	1.3452	0.0547	0.6996	0.5938	0.5938	1.3452	
MAX.	4.3592	4.0487	4.5181	15.0512	9.2422	10.3532	3.6014	2.4826	1.7232	2.4826	6.6087	6.6087	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B

Page 14 of 24

APPENDIX B (B15) Daily Flow Data for Kibos River

YEAR : ***1964***

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	1.4650	0.6458	3.2139	2.6548	5.0091	4.2027	2.0070	4.3592	3.0204	2.1588	1.7232	1.5909	2.6700
2	1.4650	0.6458	1.8618	2.8341	4.8430	3.7480	2.1588	4.0487	1.7232	2.0070	1.7232	1.1240	2.3500
3	1.4650	0.6458	2.3173	1.8618	4.3592	3.4148	2.1588	4.3592	1.7232	2.3173	1.4650	1.1240	2.2700
4	1.3452	0.6996	3.4148	1.5909	4.0487	3.6014	2.0070	6.6087	2.6548	4.0487	1.4650	1.1240	2.7200
5	1.3452	2.4826	2.3173	1.4650	4.0487	4.6794	1.7232	5.5214	1.4650	7.7777	1.5909	3.0204	3.1200
6	1.3452	1.8618	1.8618	2.0070	3.8971	4.5181	1.4650	4.8430	1.4650	3.0204	1.4650	2.4826	2.5200
7	1.2316	2.6548	1.5909	2.4826	2.8341	3.4148	1.7232	5.5214	1.4650	6.0547	1.4650	1.5909	2.6700
8	1.1240	1.3452	1.1240	2.1588	3.0204	2.8341	1.4650	4.8430	2.1588	7.5773	1.4650	1.1240	2.5200
9	1.1240	1.1240	1.0222	2.1588	3.2139	3.2139	4.0487	4.2027	1.4650	6.0547	1.7232	1.1240	2.5400
10	1.0222	1.4650	1.3452	4.8430	3.8971	2.8341	3.0204	4.2027	1.4650	5.0091	1.4650	0.8358	2.6200
11	1.0222	0.9262	0.9262	5.0091	4.5181	3.4148	2.0070	3.6014	1.4650	3.2139	1.4650	1.0222	2.3800
12	1.0222	0.8358	0.8358	3.6014	5.1775	2.8341	1.8618	3.0204	1.3452	1.5909	2.1588	0.9262	2.1000
13	1.0222	0.6996	0.7509	3.0204	4.0487	2.8341	1.7232	3.0204	1.3452	5.0091	2.6548	1.0222	2.2600
14	1.0222	0.7509	1.1240	2.6548	3.6014	2.4826	1.4650	2.8341	1.3452	5.0091	2.0070	1.5909	2.1600
15	0.8358	0.7509	1.4650	4.0487	4.0487	2.3173	1.4650	2.4826	1.4650	4.3592	1.4650	1.4650	2.1800
16	0.8358	0.6996	1.1240	3.0204	3.6014	2.3173	1.4650	3.0204	1.4650	4.5181	1.5909	0.9262	2.0500
17	1.1240	0.7509	1.0222	3.2139	3.0204	2.1588	1.4650	4.3592	1.7232	4.6794	1.4650	0.8358	2.1500
18	0.8358	0.6996	0.9262	6.0547	3.6014	2.1588	1.4650	3.2139	4.5181	4.0487	1.4650	1.0222	2.5000
19	1.0222	0.8358	0.8358	6.0547	3.0204	1.4650	1.4650	3.0204	2.0070	3.6014	2.1588	1.4650	2.2500
20	2.0070	0.7509	0.7509	6.6087	5.0091	2.0070	1.4650	2.8341	3.0204	3.6014	1.4650	1.1240	2.5500
21	1.1240	0.6996	0.7509	9.0265	4.5181	2.4826	1.4650	2.4826	3.0204	3.0204	1.4650	1.0222	2.5900
22	1.1240	0.6458	0.7509	9.0265	4.0487	2.4826	1.3452	2.4826	3.0204	2.6548	1.3452	1.1240	2.5000
23	0.8358	1.7232	0.7509	11.0453	3.4148	2.0070	1.2316	2.0070	2.6548	2.6548	1.2316	1.3452	2.5800
24	0.8358	1.4650	3.0204	16.6869	3.0204	2.0070	1.2316	2.0070	2.0070	2.4826	1.1240	1.3452	3.1000
25	0.7509	1.3452	1.7232	13.2341	2.8341	2.3173	1.5909	3.0204	2.4826	2.4826	1.4650	1.1240	2.8600
26	0.7509	1.4650	2.0070	11.7562	5.0091	1.4650	1.5909	2.0070	2.0070	2.3173	1.1240	1.4650	2.7500
27	0.7509	1.1240	3.4148	6.6087	3.6014	4.0487	1.1240	1.8618	1.8618	2.0070	1.1240	2.0070	2.4600
28	0.7509	1.1240	3.7480	7.7777	3.0204	3.0204	2.8341	2.6548	2.4826	2.4826	3.0204	1.8618	2.9000
29	0.6996	1.2316	2.3173	6.6087	3.0204	2.1588	3.4148	2.1588	2.1588	2.3173	1.2316	1.1240	2.3700
30	0.6458		2.0070	5.5214	4.8430	2.0070	4.0487	1.8618	2.1588	2.0070	1.2316	1.4650	2.5300
31	0.6458		1.5909		4.5181		4.5181	1.7232		1.8618		0.9262	2.2500
MIN.	0.6458	0.6458	0.7509	1.4650	2.8341	1.4650	1.1240	1.7232	1.3452	1.5909	1.1240	0.8358	
MAX.	2.0070	2.6548	3.7480	16.6869	5.1775	4.6794	4.5181	6.6087	4.5181	7.7777	3.0204	3.0204	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B (B16) Daily Flow Data for Kibos River

YEAR : ***1965***

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	0.8358	0.4954	0.4045	0.4954	2.0070	0.7509	0.5938	0.5437	3.6014	0.8358	1.8618	1.4650	1.1600
2	2.0070	1.1240	0.9262	0.4490	1.4650	0.8358	0.6996	0.4954	2.4826	0.7509	1.1240	1.3452	1.1400
3	1.2316	1.1240	0.8358	0.4045	6.6087	0.8358	0.6458	0.6458	1.1240	0.6996	2.0070	1.4650	1.4700
4	1.7232	1.1240	1.3452	0.4954	4.6794	1.4650	0.5938	1.8618	0.8358	0.6458	2.0070	2.4826	1.6000
5	1.3452	0.6996	1.4650	0.4954	2.6548	1.1240	0.7509	1.7232	0.7509	0.6458	2.8341	1.4650	1.3300
6	1.1240	0.6996	1.3452	0.4954	1.7232	1.0222	0.5938	0.7509	0.6458	0.5938	4.0487	1.2316	1.1900
7	1.0222	0.7509	1.0222	0.4954	1.4650	0.8358	0.6996	0.6996	0.6458	0.5437	3.8971	1.1240	1.1000
8	1.1240	0.8358	0.9290	0.4954	3.8971	0.7509	0.6458	0.8358	0.5938	0.4954	6.0547	1.1240	1.4800
9	0.9262	0.5938	0.9290	0.4045	3.6014	0.7509	0.6458	0.6458	0.6458	0.5437	3.0204	1.0222	1.1400
10	0.9262	0.5938	0.8358	0.3620	2.0070	0.6458	0.6458	0.6458	0.5437	0.4954	4.5181	0.9262	1.1000
11	0.9262	0.5938	0.8358	0.3620	1.7232	0.6996	0.5938	0.6458	0.5938	0.4954	6.0547	0.9262	1.2000
12	3.2139	0.5437	0.8358	0.3620	1.4650	0.6458	0.5938	2.0070	0.6458	0.3620	4.5181	0.8358	1.3400
13	1.4650	0.5938	0.8358	0.4490	1.4650	0.6458	0.5938	0.6996	0.5938	0.4954	5.0091	0.8358	1.1400
14	1.3452	0.4954	0.8358	1.7232	1.4650	0.6458	0.5437	0.6458	0.5938	0.4954	4.3592	1.1240	1.1900
15	0.8358	0.4954	0.8358	0.5938	1.4650	0.6458	0.4954	0.6458	0.4954	0.4954	3.0204	1.7232	0.9800
16	0.8358	0.4954	0.8358	0.5938	1.1240	0.5938	0.4954	0.6458	0.5437	0.4490	2.4826	2.0070	0.9300
17	0.8358	0.4954	1.0222	1.7232	1.0222	0.6458	0.6458	0.5437	0.4954	0.5437	2.0070	1.1240	0.9300
18	0.7509	0.4954	1.1240	0.6458	0.9262	0.7509	0.9262	0.5437	0.4490	0.4490	2.1588	2.4826	0.9800
19	0.6996	0.4954	0.9262	2.4826	1.1240	0.6996	0.8358	0.5437	0.4045	1.0222	2.1588	3.2139	1.2200
20	0.6996	0.5938	1.0222	1.8618	1.1240	1.1240	0.8358	0.8358	0.4954	1.4650	2.1588	2.4826	1.2200
21	0.6458	0.6458	0.9262	0.6996	0.8358	0.6458	1.3452	0.6996	0.4045	1.4650	2.3173	1.7232	1.0300
22	0.6996	0.5437	0.8358	4.0487	0.8358	0.6458	1.1240	0.6458	0.4954	4.6794	2.0070	1.4650	1.5000
23	0.6458	0.4954	0.8358	1.4650	2.3173	0.5938	0.7509	0.5437	0.6458	2.0070	1.4650	1.3452	1.0900
24	0.6458	0.4490	1.0222	1.4650	1.4650	0.6458	0.6996	0.6458	0.8358	3.2139	1.4650	1.5909	1.1800
25	0.6996	0.4045	1.0222	1.1240	1.1240	0.6458	0.7509	0.5938	0.6458	1.4650	1.4650	1.2316	0.9300
26	0.6458	0.4045	1.1240	1.0222	0.8358	0.6458	0.6996	0.5437	0.6458	1.2316	2.0070	1.0222	0.9000
27	0.6458	0.4045	1.8618	0.8358	0.8358	0.7509	0.6458	0.5938	0.7509	1.0222	1.8618	1.1240	0.9400
28	0.5938	0.4045	0.8358	1.1240	1.1240	0.6458	0.5938	0.5938	3.0204	1.0222	1.7232	1.1240	1.0700
29	0.5938		0.7509	6.6087	0.9262	0.6996	0.5938	0.6458	2.6548	1.1240	1.4650	1.1240	1.5600
30	0.5437		0.5938	4.5181	0.8358	0.6458	0.6458	0.6458	1.1240	2.0070	1.1240	1.0222	1.2500
31	0.5437		0.4954		1.0222		0.5437	0.5938		1.5909		0.9262	0.8200
MIN.	0.5437	0.4045	0.4045	0.3620	0.8358	0.5938	0.4954	0.4954	0.4045	0.3620	1.1240	0.8358	
MAX.	3.2139	1.1240	1.8618	6.6087	6.6087	1.4650	1.3452	2.0070	3.6014	4.6794	6.0547	3.2139	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B (B17) Daily Flow Data for Kibos River

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	0.9262	0.5938	0.8358	1.3452	5.3483	2.0070	1.1240	1.1240	1.5909	1.2316	0.8358	0.8358	1.4800
2	0.9262	0.5938	0.8358	1.3452	4.5181	2.0070	1.0222	1.0222	1.2316	0.9262	0.8358	0.7509	1.3300
3	0.8358	0.4954	0.7509	1.2316	4.3592	1.7232	1.1240	1.0222	2.6548	0.8358	0.6996	0.6458	1.3600
4	0.6996	0.4954	0.7509	1.1240	4.5181	1.5909	0.9262	0.8358	2.1588	0.8358	0.9262	0.4954	1.2800
5	0.6996	0.4954	0.8358	1.1240	4.3592	1.4650	0.9262	0.8358	1.7232	0.8358	0.8358	0.2466	1.2000
6	0.6996	0.4490	0.7509	0.8358	4.0487	1.4650	0.8358	1.0222	1.1240	0.8358	1.1240	1.3452	1.2100
7	0.6458	0.7509	0.6458	0.8358	4.5181	1.3452	1.0222	0.8358	1.4650	0.8358	1.3452	0.7509	1.2500
8	0.6458	0.7509	0.5938	0.8358	4.3592	1.3452	1.1240	0.8358	1.1240	0.7509	1.7232	0.4954	1.2200
9	0.6458	0.5938	0.5938	0.7509	3.8971	1.3452	1.3452	0.8358	1.3452	0.7509	3.0204	0.5938	1.3100
10	0.6458	0.6458	2.0070	0.9262	3.2139	1.3452	2.4826	0.8358	2.4826	1.0222	3.2139	0.5938	1.6200
11	0.6458	0.8358	1.3452	1.1240	2.4826	1.3452	1.4650	0.7509	1.4650	1.0222	2.3173	0.6458	1.2900
12	0.6458	1.0222	0.7509	5.5214	2.0070	1.3452	1.4650	0.7509	1.2316	0.7509	3.6014	0.7509	1.6500
13	0.6458	1.0222	0.6996	6.6087	2.0070	2.4826	1.5909	1.1240	1.1240	0.7509	2.8341	0.6458	1.7900
14	0.6458	1.0222	4.3592	4.5181	1.8618	1.7232	1.4650	1.0222	1.1240	0.6996	2.6548	1.4650	1.8800
15	0.6458	0.4954	1.7232	6.6087	1.7232	1.4650	1.2316	1.1240	1.1240	0.6996	2.0070	0.7509	1.6300
16	0.6458	0.5938	2.0070	6.7979	1.4650	2.0070	1.4650	1.1240	1.1240	0.8358	1.7232	0.6458	1.7000
17	0.6458	0.6458	1.7232	6.0547	1.4650	2.0070	1.7232	0.9262	0.8358	1.1240	1.5909	0.5938	1.6100
18	0.6458	0.6996	1.3452	5.8746	1.3452	1.4650	1.5909	0.8358	0.8358	1.1240	1.2316	0.5938	1.4700
19	0.6458	0.6458	1.3452	5.0091	2.4826	1.4650	1.4650	0.8358	0.8358	0.6996	1.0222	0.5938	1.4200
20	0.6458	0.9262	1.4650	3.8971	1.7232	1.4650	1.3452	1.0222	1.0222	0.9262	1.0222	0.4954	1.3300
21	0.6458	0.5938	3.0204	4.5181	1.4650	1.4650	1.3452	0.9262	0.8358	0.6996	1.4650	0.4045	1.4500
22	0.6458	2.4826	2.4826	4.3592	2.0070	1.2316	2.4826	3.0204	0.7509	0.6996	1.4650	0.4954	1.8400
23	0.6458	0.7509	1.4650	4.3592	2.0070	1.3452	2.3173	2.0070	1.1240	0.8358	1.1240	0.4045	1.5300
24	0.5938	1.0222	2.1588	4.2027	2.4826	1.4650	1.2316	1.4650	1.0222	0.7509	1.1240	0.4045	1.4900
25	0.6458	1.0222	3.8971	15.0512	6.0547	1.1240	1.1240	1.4650	2.4826	0.6996	1.0222	0.4045	2.9200
26	0.6458	0.8358	4.3592	14.0008	3.8971	1.4650	1.1240	1.1240	2.3173	0.6458	2.6548	0.4954	2.8000
27	0.6458	0.6996	4.5181	9.4602	2.6548	1.1240	1.4650	1.0222	1.1240	0.6996	2.6548	0.4490	2.2100
28	0.5938	0.8358	2.1588	6.6087	2.4826	2.0070	1.3452	5.0091	1.4650	1.0222	2.3173	0.4490	2.1900
29	0.4954		2.0070	6.0547	2.0070	1.4650	1.3452	2.4826	2.4826	1.0222	2.1588	0.4954	2.0000
30	0.4490		1.4650	5.5214	2.1588	1.4650	1.1240	1.7232	1.5909	0.9262	2.0070	0.4954	1.7200
31	0.5938		1.3452		2.4826		1.1240	2.0070		1.1240		0.4954	1.3100
MIN.	0.4490	0.4490	0.5938	0.7509	1.3452	1.1240	0.8358	0.7509	0.7509	0.6458	0.6996	0.2466	
MAX.	0.9262	2.4826	4.5181	15.0512	6.0547	2.4826	2.4826	5.0091	2.6548	1.2316	3.6014	1.4650	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B (B18) Daily Flow Data for Kibos River

YEAR : ***1967***

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	0.4954	0.7509	0.6458	2.6548	1.4650	2.4826	3.0204	0.6996	0.7509	1.4650	1.1240	6.7979	1.8600
2	0.4045	0.6458	1.1240	1.4650	4.8430	2.1588	3.2139	0.6458	0.7509	1.4650	0.7509	13.2341	2.5600
3	0.4045	0.6458	0.6458	1.4650	2.3173	1.8618	2.1588	0.6458	0.7509	2.0070	0.7509	8.3923	1.8400
4	0.8358	0.6458	0.6458	1.1240	2.0070	1.4650	1.4650	0.6458	0.7509	1.1240	0.7509	7.1831	1.5500
5	0.8358	0.6458	0.8358	1.3452	1.4650	1.3452	1.2316	0.6458	0.7509	1.1240	0.6996	5.6968	1.3900
6	0.7509	0.6458	0.8358	1.7232	1.3452	1.1240	1.1240	0.7509	0.7509	1.0222	0.7509	5.3483	1.3500
7	0.7509	1.0222	0.8358	0.8358	2.0070	1.1240	1.0222	0.6458	0.7509	1.0222	0.6996	5.0091	1.3100
8	0.6458	1.0222	0.6996	0.7509	2.0070	1.1240	1.0222	0.7509	0.7509	1.0222	0.6458	4.5181	1.2500
9	0.5938	0.8358	0.6458	0.7509	1.7232	1.1240	1.0222	1.0222	0.7509	0.9262	0.6458	3.6014	1.1400
10	0.5938	0.8358	0.6458	0.5938	1.4650	1.1240	0.8358	1.3452	0.7509	0.8358	0.6458	3.0204	1.0600
11	0.4954	0.8358	0.6458	2.0070	1.4650	1.1240	0.8358	1.4650	0.7509	0.9262	0.7509	2.6548	1.1600
12	0.6458	0.7509	0.6458	1.3452	3.0204	1.1240	1.0222	1.4650	0.7509	0.8358	0.7509	2.6548	1.2500
13	0.4954	0.6458	0.6458	1.4650	3.0204	1.1240	0.8358	1.0222	0.7509	0.8358	0.8358	2.3173	1.1700
14	0.4954	0.6458	0.6458	0.8358	2.0070	1.1240	0.8358	0.8358	0.7509	0.7509	0.8358	1.8618	0.9700
15	0.4954	0.6458	0.6458	1.4650	1.7232	1.1240	0.8358	0.7509	0.7509	0.7509	1.4650	1.5909	1.0200
16	0.4954	0.6458	0.6458	1.4650	1.4650	1.0222	0.9262	0.6996	0.7509	0.7509	1.1240	1.4650	0.9500
17	0.7509	0.6458	0.6458	0.8358	2.1588	1.0222	0.7509	0.6458	1.0222	0.7509	1.3452	2.0070	1.0500
18	0.7509	0.6458	0.6458	0.8358	1.4650	0.8358	0.7509	1.4650	1.4650	0.9262	1.7232	1.7232	1.1000
19	0.7509	0.6458	0.6458	0.8358	1.7232	0.8358	0.8358	1.4650	1.5909	0.7509	5.5214	4.5181	1.6800
20	0.7509	0.5938	0.6458	0.8358	1.7232	1.4650	0.6458	1.0222	1.4650	0.8358	4.0487	3.0204	1.4200
21	0.7509	0.6458	0.6996	0.7509	1.7232	1.2316	1.1240	1.1240	1.4650	1.1240	3.8971	2.4826	1.4200
22	0.6996	0.6458	0.7509	0.7509	1.8618	1.2316	1.0222	0.8358	1.4650	0.9262	4.5181	1.8618	1.3800
23	1.0222	0.6458	0.6458	0.4954	2.4826	2.0070	0.9262	0.8358	1.4650	1.0222	5.0091	1.7232	1.5200
24	2.4826	0.6458	0.6458	0.4954	2.0070	2.4826	1.1240	0.8358	1.4650	1.3452	3.2139	1.5909	1.5300
25	2.6548	0.6458	0.6458	0.5938	1.4650	2.1588	1.1240	0.8358	5.5214	1.4650	1.5909	1.4650	1.6800
26	0.9262	0.6458	0.6458	0.6458	1.4650	1.2316	0.9262	0.7509	2.4826	1.3452	1.7232	1.5909	1.2000
27	0.8358	0.6458	0.7509	0.6458	1.3452	1.1240	0.8358	0.7509	2.0070	1.3452	13.2341	1.4650	2.0800
28	0.8358	0.6458	0.7509	1.3452	1.3452	1.1240	0.8358	0.7509	1.4650	1.3452	13.2341	1.4650	2.1000
29	0.8358		0.8358	1.1240	3.2139	1.4650	0.8358	0.7509	1.3452	1.2316	9.0265	1.3452	2.0000
30	0.7509		0.8358	2.3173	1.8618	1.4650	0.8358	0.7509	1.4650	1.3452	6.0547	1.2316	1.7200
31	0.7509		4.3592		2.0070		0.7509	0.7509		1.2316		1.1240	1.5700
MIN.	0.4045	0.5938	0.6458	0.4954	1.3452	0.8358	0.6458	0.6458	0.7509	0.7509	0.6458	1.1240	
MAX.	2.6548	1.0222	4.3592	2.6548	4.8430	2.4826	3.2139	1.4650	5.5214	2.0070	13.2341	13.2341	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B (B19) Daily Flow Data for Kibos River

YEAR : ***1968***

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	1.3452	1.0222	1.7232	1.4650	12.2406	6.6087	2.3173	1.1240	1.2316	1.9514	1.5329	2.1018	2.8900
2	1.3452	1.0222	1.4650	2.0070	9.6802	6.0547	3.6014	1.3452	1.1240	2.0728	1.4339	2.0823	2.7700
3	1.1240	1.4650	1.5909	2.0070	9.6802	4.8430	3.2139	1.2316	1.1240	2.2499	1.9316	2.2022	2.7200
4	1.1240	1.4650	1.3452	1.4650	9.0265	4.0487	3.0204	1.1240	1.1240	2.0343	1.6097	1.8414	2.4400
5	1.1240	1.4650	1.1240	1.4650	6.6087	4.0487	2.4826	2.4826	1.1240	2.3549	1.7796	1.7000	2.3100
6	1.1240	1.3452	15.0512	2.6548	6.0547	4.2027	2.1588	3.0204	2.0070	1.8301	2.0206	1.6735	3.6000
7	1.1240	1.1240	2.6548	2.4826	5.5214	4.5181	2.4826	3.0204	1.1240	2.0760	1.6319	1.5918	2.4500
8	1.1240	1.1240	2.4826	3.2139	4.8430	4.3592	2.4826	2.6548	3.6014	2.0560	1.7508	1.5451	2.6000
9	1.0222	1.0222	2.1588	4.5181	4.3592	3.6014	2.3173	1.4650	2.0070	1.8034	1.8646	1.6760	2.3200
10	1.0222	0.8358	3.0204	3.8971	3.2139	2.6548	2.1588	1.4650	1.4650	1.6973	2.0724	1.5816	2.0900
11	0.9262	0.6996	2.6548	3.0204	3.0204	4.0487	2.0070	1.3452	1.2316	1.5028	2.2390	1.5411	2.0200
12	0.8358	0.6458	2.1588	2.4826	3.2139	3.8971	1.4650	1.4650	3.6014	1.3157	1.8768	1.5859	2.0500
13	0.8358	3.0204	2.0070	3.0204	4.0487	4.8430	1.3452	1.4650	2.8341	1.5663	1.8522	1.5140	2.3600
14	0.8358	6.6087	6.6087	2.1588	4.0487	6.0547	1.3452	1.4650	3.8971	1.4242	1.8142	1.7075	3.1600
15	0.8358	6.4217	6.0547	1.7232	3.8971	5.3483	1.4650	1.4650	3.0204	1.3333	1.6256	1.5526	2.9000
16	0.8358	5.3483	5.0091	1.7232	3.8971	4.8430	1.4650	2.4826	2.0070	1.2702	1.5270	1.6017	2.6700
17	0.7509	5.0091	4.0487	1.4650	3.6014	5.3483	1.4650	2.6548	1.4650	1.1881	1.8493	1.7649	2.5500
18	0.7509	5.5214	4.3592	1.4650	3.6014	5.5214	1.4650	1.4650	1.7232	1.4377	1.9250	1.7159	2.5800
19	0.7509	6.0547	3.8971	2.0070	2.4826	8.3923	1.3452	2.0070	1.8618	1.4609	2.1414	1.8061	2.8500
20	0.7509	6.4217	3.0204	1.4650	2.0070	9.0265	1.3452	2.3173	3.0204	1.2684	2.0832	1.7481	2.8700
21	0.7509	6.4217	5.0091	1.4650	3.8971	9.6802	1.1240	1.4650	2.6548	1.3649	2.1002	1.6878	3.1400
22	0.7509	6.4217	3.6014	2.8341	3.0204	9.0265	1.1240	1.8618	2.3173	1.4808	2.0139	1.6200	3.0100
23	0.7509	6.6087	3.0204	12.4859	3.0204	9.0265	1.4650	3.6014	2.0070	1.6495	1.6935	1.5953	3.9100
24	0.7509	6.6087	2.4826	7.1831	3.2139	6.0547	1.4650	1.5909	2.3173	1.6010	1.8303	1.4507	3.0500
25	0.7509	2.8341	2.1588	6.0547	3.6014	5.5214	2.0070	1.4650	1.4650	1.6468	1.5407	1.5262	2.5500
26	0.7509	2.4826	2.0070	6.2371	3.0204	4.5181	2.4826	1.4650	2.0070	1.7269	1.6841	1.6546	2.5000
27	0.7509	1.8618	1.4650	7.1831	3.6014	3.6014	2.3173	1.4650	3.0204	1.4497	2.4955	1.4233	2.5500
28	0.6996	2.4826	1.4650	12.9827	3.2139	2.4826	1.4650	1.5909	2.0070	1.3712	2.5106	1.3691	2.8000
29	0.6458	2.1588	1.4650	13.2341	2.6548	2.4826	1.7232	2.4826	1.8618	1.3286	2.4270	1.5808	2.8400
30	1.1240		1.4650	12.7374	6.6087	1.8618	1.4650	1.4650	1.8618	1.4329	2.1487	1.4699	3.0600
31	1.0222		1.1240		3.2139		1.4650	1.4650		1.4983		1.5062	1.6100
MIN.	0.6458	0.6458	1.1240	1.4650	2.0070	1.8618	1.1240	1.1240	1.1240	1.1881	1.4339	1.3691	
MAX.	1.3452	6.6087	15.0512	13.2341	12.2406	9.6802	3.6014	3.6014	3.8971	2.3549	2.5106	2.2022	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B (B20) Daily Flow Data for Kibos River

YEAR : ***1969***

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	1.6180	0.8350	0.9776	0.8358	1.2316	1.5909	1.4650	1.4650	0.8358	1.9514	2.0070	0.6458	1.2900
2	1.4450	0.7996	1.0592	0.8358	1.4650	1.5909	1.1240	1.3452	0.8358	2.0728	2.0070	0.5938	1.2600
3	1.4151	0.8087	1.0570	0.8358	1.4650	1.4650	1.1240	2.1588	0.8358	2.2499	2.0070	0.6458	1.3400
4	1.2628	0.8136	0.9434	0.8358	2.0070	1.4650	1.1240	1.4650	0.8358	2.0343	0.8358	0.6458	1.1900
5	1.3953	0.8408	0.9472	0.8358	2.0070	1.3452	1.1240	1.4650	0.8358	2.3549	0.7509	0.6458	1.2100
6	1.3269	0.7549	1.4796	0.8358	3.0204	1.4650	0.6458	1.4650	0.8358	1.8301	0.6458	0.5938	1.2400
7	1.2913	0.8252	0.9584	0.8358	2.6548	1.4650	0.5938	1.1240	1.5909	2.0760	0.8358	0.4954	1.2300
8	1.1838	1.0621	0.8253	0.8358	3.6014	1.4650	1.1240	0.8358	0.8358	2.0560	0.8358	0.4954	1.2600
9	1.2478	0.9270	0.8577	0.8358	3.0204	1.7232	1.1240	1.3452	0.8358	1.8034	0.6458	0.4954	1.2400
10	1.2937	0.9965	0.8954	0.8358	2.0070	2.1588	1.1240	1.1240	0.8358	1.6973	0.6458	0.5938	1.1800
11	1.2814	0.8090	0.8328	1.0222	3.7480	2.1588	1.1240	1.4650	2.8341	1.5028	0.6458	0.4954	1.4900
12	1.2003	0.8425	0.8944	1.1240	3.2139	2.1588	2.0070	1.3452	3.0204	1.3157	0.6996	0.4954	1.5300
13	1.0592	0.9016	0.8315	1.1240	4.0487	2.0070	1.4650	1.4650	2.0070	1.5663	0.7509	0.4954	1.4800
14	1.0184	1.0875	1.0886	1.1240	3.8971	2.1588	1.1240	3.2139	1.4650	1.4242	0.6458	0.4954	1.5600
15	0.9836	1.0691	0.9959	1.1240	4.5181	2.1588	1.0222	2.6548	2.4826	1.3333	0.8358	0.4490	1.6400
16	1.1171	1.1218	0.9190	1.0222	4.0487	2.1588	0.8358	3.6014	2.4826	1.2702	0.7509	0.4045	1.6400
17	1.1602	1.0343	1.3986	1.0222	3.6014	5.5214	0.8358	3.6014	2.4826	1.1881	0.7509	0.4045	1.9200
18	1.0002	1.0077	1.1331	0.8358	3.4148	3.0204	0.8358	3.6014	1.8618	1.4377	0.7509	0.2830	1.6000
19	1.1630	1.1839	1.0959	1.5909	4.0487	2.1588	0.8358	1.4650	1.4650	1.4609	0.6458	0.4954	1.4700
20	1.0852	1.0663	0.9353	1.4650	3.8971	2.4826	0.8358	1.3452	2.6548	1.2684	0.7509	0.5437	1.5300
21	0.9975	1.0615	1.3725	2.0070	3.0204	2.0070	1.1240	1.1240	3.0204	1.3649	0.6458	0.4954	1.5200
22	1.1436	1.2067	1.2756	1.1240	2.6548	1.7232	1.4650	1.0222	3.0204	1.4808	0.6458	0.4045	1.4300
23	1.0437	1.2340	1.0574	0.8358	2.4826	1.4650	1.4650	0.8358	1.4650	1.6495	0.6458	0.4045	1.2200
24	1.0803	1.1249	1.1197	0.7509	2.3173	2.0070	1.4650	0.8358	2.8341	1.6010	0.6458	0.4045	1.3500
25	1.0603	0.8851	1.2182	0.7509	2.3173	2.0070	1.4650	0.9262	2.0070	1.6468	1.1240	0.3620	1.3100
26	0.9139	0.9159	1.3879	0.7509	3.0204	1.7232	1.4650	0.8358	1.4650	1.7269	0.7509	0.3620	1.2800
27	0.9290	0.7896	1.2932	0.7509	3.6014	1.4650	1.4650	0.8358	0.7509	1.4497	0.6458	0.3620	1.1900
28	0.9427	0.8871	2.2927	0.6458	4.0487	1.4650	2.1588	0.8358	0.7509	1.3712	0.6458	0.4045	1.3700
29	0.8682		1.2971	1.1240	4.5181	2.0070	3.0204	0.8358	0.6458	1.3286	0.6458	0.3620	1.5100
30	0.8562		1.1849	1.1240	3.0204	1.4650	2.4826	0.8358	0.6458	1.4329	0.6458	1.1240	1.3500
31	0.9494		1.2237		2.6548		1.3452	1.0222		1.4983		0.4954	1.3100
MIN.	0.8562	0.7549	0.8253	0.6458	1.2316	1.3452	0.5938	0.8358	0.6458	1.1881	0.6458	0.2830	
MAX.	1.6180	1.2340	2.2927	2.0070	4.5181	5.5214	3.0204	3.6014	3.0204	2.3549	2.0070	1.1240	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B (B21) Daily Flow Data for Kibos River

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	0.3620	2.3173	0.4954	3.7480	4.0487	2.6548	1.4650	0.8358	0.8358	1.9514	0.6996	0.8358	1.6900
2	0.3620	1.4650	0.5938	2.0070	2.6548	2.4826	2.4826	0.8358	0.7553	2.0728	0.6458	0.8358	1.4300
3	0.3620	1.4650	0.4954	1.8618	3.8971	2.4826	1.4650	1.0222	0.6996	2.2499	1.1240	0.9262	1.5000
4	0.3620	1.3452	0.4954	1.4650	3.6014	2.4826	1.4650	0.8358	0.6996	2.0343	1.4650	0.8358	1.4200
5	0.3620	1.1240	0.4490	2.4826	3.6014	4.5181	1.8618	1.0222	0.6996	2.3549	1.4650	0.8358	1.7300
6	0.8358	1.0222	0.3620	2.4826	3.0204	3.7480	1.4650	0.8358	0.6458	1.8301	8.8129	0.8358	2.1600
7	1.4650	1.0222	0.3620	1.8618	3.6014	3.6014	1.3452	0.7509	0.8358	2.0760	2.4826	0.7509	1.6800
8	2.0070	1.0222	0.3620	1.4650	3.6014	2.4826	1.1240	0.7509	0.6458	2.0560	2.0070	0.7509	1.5200
9	1.7232	1.1240	0.4045	1.4650	4.6794	1.7232	1.1240	0.8358	0.6458	1.8034	3.8971	0.7509	1.6800
10	1.4650	1.1240	1.2316	1.8618	5.0091	1.8618	1.1240	0.7509	0.5938	1.6973	2.0070	0.8358	1.6300
11	1.4650	1.1240	1.1240	2.0070	3.7480	1.5909	1.1240	0.8358	2.8341	1.5028	1.4650	0.7509	1.6300
12	1.4650	1.1240	0.8358	1.7232	3.4148	1.7232	1.1240	0.7509	2.6548	1.3157	1.0222	0.7509	1.4900
13	1.4650	1.1240	0.7509	2.1588	3.8971	1.5909	1.0222	1.4650	0.8358	1.5663	1.1240	0.7509	1.4800
14	1.4650	0.8358	0.6458	1.4650	3.8971	1.5909	0.8358	1.0222	1.1240	1.4242	1.1240	1.0222	1.3700
15	1.2316	1.1240	0.8358	1.4650	3.2139	1.4650	0.8358	0.8358	1.4650	1.3333	0.8358	0.8358	1.2900
16	1.2316	1.0222	0.8358	1.2316	2.6548	1.8618	0.8358	1.0222	1.2316	1.2702	1.7232	3.7480	1.5600
17	1.1240	1.0222	6.4217	1.5909	2.4826	1.5909	0.8358	1.3452	1.1246	1.1881	1.1240	3.6014	1.9500
18	1.1240	0.8358	3.2139	1.3452	2.1588	1.4650	0.9262	1.0222	1.4650	1.4377	1.0222	1.8618	1.4900
19	1.1240	1.1240	1.8618	2.0070	2.1588	1.4650	0.8358	0.8358	1.4650	1.4609	0.8358	1.4650	1.3900
20	1.5909	1.0222	1.1240	1.3452	1.8618	1.2316	0.8358	0.7509	0.8358	1.2684	0.8358	1.3452	1.1700
21	1.1240	1.1240	1.1240	1.8618	1.7232	1.1240	0.8358	1.0222	1.4650	1.3649	1.4650	1.1240	1.2800
22	3.6014	1.0222	1.0222	4.5181	1.5909	1.4650	0.9262	1.0222	1.1240	1.4808	1.5909	1.1240	1.7100
23	1.4650	3.0204	1.0222	3.8971	2.3173	1.5909	0.8358	0.9262	0.8358	1.6495	3.0204	1.0222	1.8000
24	1.5909	1.1240	0.9262	4.0487	2.1588	1.4650	0.8358	0.8358	1.0222	1.6010	2.1588	1.0222	1.5700
25	2.0070	1.1240	1.5909	4.2806	1.4650	1.5909	0.7509	3.0204	2.4826	1.6468	1.4650	0.8358	1.8500
26	1.4650	1.1240	1.4651	4.0487	2.0070	2.0070	0.7509	1.4650	1.1240	1.7269	1.2316	0.6458	1.5900
27	1.2316	0.5938	2.4826	3.0204	1.4650	1.4650	0.9262	1.1240	1.0222	1.4497	1.1240	0.7509	1.3900
28	1.5909	0.4954	5.1775	2.3173	1.8618	1.4650	0.9262	0.8358	1.1240	1.3712	1.0222	0.6458	1.5700
29	1.4650		5.3483	3.6014	2.6548	1.4650	0.8358	0.8358	0.9262	1.3286	0.9262	0.8358	1.8400
30	1.5909		5.0091	2.6548	3.6014	1.4650	0.8358	0.8358	0.6458	1.4329	0.9262	0.8358	1.8000
31	4.0487		2.4826		3.0204		0.7509	0.8358		1.4983		1.8618	2.0700
MIN.	0.3620	0.4954	0.3620	1.2316	1.4650	1.1240	0.7509	0.7509	0.5938	1.1881	0.6458	0.6458	
MAX.	4.0487	3.0204	6.4217	4.5181	5.0091	4.5181	2.4826	3.0204	2.8341	2.3549	8.8129	3.7480	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B (B22) Daily Flow Data for Kibos River

YEAR : ***1971***

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	0.9262	0.4954	0.7509	0.6458	1.1240	2.0070	0.8358	1.1240	2.3173	1.4650	1.3452	0.6458	1.1400
2	0.9262	0.4954	0.7509	0.6996	0.9262	1.7232	0.8358	1.1240	2.0070	2.1588	0.8358	0.5938	1.0900
3	0.6996	0.6996	0.7509	1.0222	1.0222	3.8971	0.8358	1.0222	2.0070	1.4650	0.8358	0.5938	1.2400
4	0.8358	0.5938	0.7509	0.8358	0.6996	2.1588	0.8358	1.1240	2.6548	2.4826	0.8358	0.5938	1.2000
5	0.7509	0.4954	0.7509	1.2316	0.8358	1.7232	0.8358	0.9262	2.4826	2.0059	0.8358	0.5437	1.1200
6	0.7509	0.4954	0.6458	1.1240	0.8358	1.4650	0.6458	0.8358	2.4826	1.4650	0.8358	0.5437	1.0100
7	0.6996	0.4954	0.6458	2.4826	0.8358	1.4650	0.8358	0.8358	3.8971	1.5909	0.7509	0.4954	1.2500
8	0.6458	1.0222	0.6458	1.0222	0.8358	1.4650	0.9262	1.0222	2.4826	1.4650	0.7509	0.5437	1.0700
9	0.5938	0.8358	0.6458	0.6996	0.9262	1.3452	0.8358	0.8358	2.0070	1.3452	1.0222	0.4954	0.9700
10	0.5938	0.8358	0.6458	0.6459	1.0222	1.1240	0.8358	0.7509	2.4826	1.3452	0.8358	0.4954	0.9700
11	0.4954	0.8358	0.7509	0.7509	1.3452	1.3452	0.7509	1.1240	2.0070	1.4650	0.8358	0.4954	1.0200
12	0.5437	0.8358	0.6996	0.6458	1.3452	1.4650	0.7509	3.6014	1.4650	1.4650	1.4650	0.4490	1.2300
13	0.5938	0.8358	0.7509	0.6458	1.4650	1.4650	0.8358	4.0487	3.0204	1.1240	1.1240	0.4954	1.3700
14	0.5437	0.8358	0.6996	3.0204	2.0070	1.1240	0.9262	3.2139	2.6548	1.0222	1.0222	0.4490	1.4600
15	0.5938	0.7509	0.6996	3.4148	3.6014	1.1240	0.9262	3.0204	2.3173	1.0222	0.8358	0.4954	1.5700
16	0.5938	0.7509	0.6996	2.1588	3.6014	1.1240	0.9262	2.8341	2.8341	1.0222	0.7509	0.4954	1.4800
17	0.6458	0.7509	0.6458	2.6548	9.6802	1.1240	1.4650	1.4650	2.1588	1.0222	0.8358	0.5938	1.9200
18	0.6458	0.7509	0.6458	1.3452	6.6087	1.1240	2.1588	1.4650	2.0070	1.4650	0.8358	0.6996	1.6500
19	0.6458	0.7509	0.6458	1.4650	6.0547	1.0222	1.1240	1.3452	1.7232	1.1240	0.8358	0.4954	1.4400
20	0.6458	0.7509	0.6458	1.3452	4.5181	1.0222	2.0070	1.2316	1.7232	1.1240	0.6458	0.4954	1.3500
21	0.6458	0.7509	0.6458	1.3452	6.0547	1.0222	2.0070	1.4650	1.7232	1.3452	0.6458	1.4650	1.5900
22	0.7509	0.7509	0.6458	4.8430	5.0091	0.9262	1.2316	3.8971	1.7232	1.1240	0.7509	2.1588	1.9800
23	0.6458	0.7509	0.6458	2.6548	4.5181	1.2316	1.0222	4.0487	1.5909	1.0222	0.6458	1.0222	1.6500
24	0.6458	0.7509	0.5938	2.4826	4.0487	0.8358	1.0222	2.6548	2.0070	1.0222	0.6458	2.0070	1.5600
25	0.5938	0.7509	0.5938	2.1588	3.6014	0.8358	0.8358	2.6548	1.7232	0.9262	0.6458	3.2139	1.5400
26	0.4954	0.7509	0.6458	1.8618	3.6014	0.8358	0.8358	2.8341	1.8618	0.8358	0.6458	1.4650	1.3900
27	0.5437	0.7509	0.6458	1.4650	3.4148	0.8358	3.0204	2.6548	1.5909	1.1240	0.6458	1.1240	1.4800
28	0.5437	0.7509	0.6996	1.4650	2.4826	0.8358	2.0070	2.4826	2.0070	1.3452	0.8358	1.1240	1.3800
29	0.4954		0.8358	1.4650	3.0204	1.1240	1.4650	2.1588	1.7232	1.0222	0.8358	2.3173	1.5000
30	0.4954		0.7509	1.4650	2.1588	0.8358	1.4650	2.4826	1.4650	1.0222	0.8358	1.0222	1.2700
31	0.4954		0.6996		2.0070		1.3452	4.0487		1.1240		0.8358	1.5100
MIN.	0.4954	0.4954	0.5938	0.6458	0.6996	0.8358	0.6458	0.7509	1.4650	0.8358	0.6458	0.4490	
MAX.	0.9262	1.0222	0.8358	4.8430	9.6802	3.8971	3.0204	4.0487	3.8971	2.4826	1.4650	3.2139	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B (B23) Daily Flow Data for Kibos River

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake

Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	0.8358	0.4954	0.4954	0.2466	5.0091	3.0554	2.3173	2.0070	1.8618	1.9514	1.5329	2.1018	1.8300
2	0.8358	0.6458	1.4650	0.2466	4.0487	2.7871	2.1588	1.8618	1.7232	2.0728	1.4339	2.0823	1.7800
3	0.6996	0.5938	0.6458	0.2466	1.8618	2.7799	1.5909	1.4650	1.7232	2.2499	1.9316	2.2022	1.5000
4	0.6458	0.5437	0.4954	0.2466	1.3452	2.6197	1.7232	1.4650	1.4650	2.0343	1.6097	1.8414	1.3400
5	0.6458	0.5938	0.4954	0.2466	1.2316	2.8811	2.3173	1.4650	1.7232	2.3549	1.7796	1.7000	1.4500
6	0.6458	0.5437	0.4954	0.2466	1.2316	2.5363	1.8618	1.2316	1.8618	1.8301	2.0206	1.6735	1.3500
7	0.5938	0.7509	0.4954	0.2466	2.0070	2.4425	1.7232	1.1240	2.0070	2.0760	1.6319	1.5918	1.3900
8	0.5938	0.6996	0.3620	0.2466	1.3452	2.3759	1.8618	1.3452	1.8618	2.0560	1.7508	1.5451	1.3400
9	0.5437	0.6458	0.3620	0.3620	1.0222	2.2665	1.4650	1.7232	1.7232	1.8034	1.8646	1.6760	1.2900
10	0.4954	0.4954	0.3620	0.9262	1.2316	2.2365	1.8618	1.5909	1.7232	1.6973	2.0724	1.5816	1.3600
11	0.5938	0.4954	0.9262	0.5938	1.1240	2.1598	1.7232	3.2139	1.4650	1.5028	2.2390	1.5411	1.4600
12	0.4954	0.4954	0.6458	0.4490	0.8358	2.1029	1.7232	2.6548	1.3452	1.3157	1.8768	1.5859	1.2900
13	0.4954	0.4954	0.5938	0.3620	1.4650	2.0748	1.7232	1.4650	1.4650	1.5663	1.8522	1.5140	1.2600
14	0.5437	0.4490	1.3452	0.2830	1.0222	2.0090	1.4650	1.5909	1.7232	1.4242	1.8142	1.7075	1.2800
15	0.4954	0.5437	0.8358	0.8358	1.0222	1.8520	1.4650	2.0070	2.0070	1.3333	1.6256	1.5526	1.3000
16	0.4954	0.4954	0.6996	0.7509	4.8430	1.9385	1.5909	4.5181	1.8618	1.2702	1.5270	1.6017	1.8000
17	0.4954	0.5938	0.6458	0.4954	3.6014	2.0822	1.5909	3.2139	1.4650	1.1881	1.8493	1.7649	1.5800
18	0.4954	0.5938	0.4954	0.4045	3.4148	1.9318	1.4650	2.6548	1.3452	1.4377	1.9250	1.7159	1.4900
19	0.4045	0.5437	0.5938	0.3620	3.8971	1.8430	1.5909	2.0070	1.3452	1.4609	2.1414	1.8061	1.5000
20	0.4045	0.4954	0.4954	0.5938	4.5181	2.0513	1.4650	2.0070	1.3452	1.2684	2.0832	1.7481	1.5400
21	0.4045	0.4954	0.4954	0.8358	4.0487	1.8680	1.7232	2.0070	1.1240	1.3649	2.1002	1.6878	1.5100
22	0.4045	0.4045	0.4954	0.4954	2.8341	1.9708	3.0204	6.6087	1.7232	1.4808	2.0139	1.6200	1.9200
23	0.4045	0.4954	0.4490	0.4045	3.6014	1.9956	1.5909	4.5181	2.0070	1.6495	1.6935	1.5953	1.7000
24	0.4045	0.3620	0.3620	0.4954	3.2139	2.0065	1.7232	5.0091	2.8341	1.6010	1.8303	1.4507	1.7700
25	0.4045	0.8358	0.4045	0.5938	2.1588	1.8077	1.4650	4.5181	2.8341	1.6468	1.5407	1.5262	1.6400
26	0.4045	0.6458	0.4045	0.4045	2.0070	1.7024	2.0070	3.0204	3.7480	1.7269	1.6841	1.6546	1.6200
27	0.4045	0.4954	0.4045	0.3620	1.7232	1.9009	1.7232	3.0204	2.4826	1.4497	2.4955	1.4233	1.4900
28	0.4045	0.6458	0.3620	1.4650	2.0070	2.0270	1.4650	1.4650	2.0070	1.3712	2.5106	1.3691	1.4200
29	0.4045	0.4954	0.3620	2.4826	1.3452	1.9073	1.2316	2.0070	2.0070	1.3286	2.4270	1.5808	1.4600
30	0.4045		0.2830	4.5181	1.2316	2.3173	1.2316	2.3173	1.5906	1.4329	2.1487	1.4699	1.7200
31	0.3620		0.2466		2.8662		1.2316	2.0070		1.4983		1.2316	1.3500
MIN.	0.3620	0.3620	0.2466	0.2466	0.8358	1.7024	1.2316	1.1240	1.1240	1.1881	1.4339	1.2316	
MAX.	0.8358	0.8358	1.4650	4.5181	5.0091	3.0554	3.0204	6.6087	3.7480	2.3549	2.5106	2.2022	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

APPENDIX B (B24) Daily Flow Data for Kibos River YEAR : ***1973***

River Name: Kibos River
Station #: RGS 1HA04
Location: At the existing Kajulu Water Supply Diversion Intake
Longitude: 34 48' 15"
Latitude: 00 60' 30"
Catchment Area: 117 km2

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	1.1240	1.1240	1.1240	0.4490	0.6458	2.0070	1.4650	1.1240	1.4651	1.4650	1.1240	1.0222	1.1800
2	1.1240	1.0222	1.0222	0.4490	0.7509	1.7232	1.1240	1.1240	1.7227	1.4650	1.0222	0.9262	1.1200
3	1.1240	1.0222	0.9262	0.4490	1.4651	3.0204	0.8358	1.0222	1.0230	1.3452	1.0222	0.8358	1.1700
4	1.1240	0.9262	0.8358	0.4954	0.8358	2.0070	0.9262	1.8618	2.8305	1.3452	1.1240	0.8358	1.2600
5	5.6968	0.8358	0.8358	0.4491	1.4650	1.1240	1.0222	1.0222	1.1240	1.1240	1.0222	0.8358	1.3800
6	3.2139	0.8358	0.8358	0.4490	0.7509	1.2316	0.9262	0.9262	0.8358	2.0070	1.4650	0.8358	1.1900
7	1.4650	1.0222	0.8358	0.4490	1.8618	1.2316	0.8358	0.9262	1.4650	1.3452	0.8358	0.7509	1.0900
8	1.7232	0.9262	0.8358	0.4490	2.6548	1.4650	0.8358	1.0222	1.3452	1.4650	2.0070	0.7509	1.2900
9	1.4650	1.0222	0.8358	0.4954	2.1588	1.3452	0.8358	1.0222	1.1240	1.4650	1.7232	0.6996	1.1800
10	1.4650	1.1240	0.6458	0.4954	1.7232	1.1240	0.7509	0.8358	1.1240	1.3452	2.4826	0.6996	1.1500
11	1.4650	1.1240	0.6458	0.4954	1.4650	1.0222	0.6996	1.1240	2.1588	1.3452	2.1588	0.7509	1.2000
12	2.0070	1.1240	0.5938	1.7232	2.4826	1.7232	0.6996	2.6548	2.0070	1.1240	2.1588	0.6996	1.5800
13	1.4650	1.4650	0.6458	1.1585	2.3173	1.4650	0.6996	1.1240	1.4650	1.0222	1.4650	0.6458	1.2400
14	1.4650	1.0222	0.5437	0.5938	1.8618	1.0222	0.6458	1.4650	2.0070	1.1240	1.4650	0.6458	1.1600
15	2.0070	1.0222	0.5437	0.5437	2.4826	1.1240	0.7509	1.1240	3.4092	1.4650	1.1240	0.6458	1.3500
16	3.6014	1.1240	0.4954	0.6458	2.1588	1.4650	0.7509	1.3456	2.4826	2.4826	1.3452	0.6458	1.5500
17	3.0204	0.8358	0.6458	2.4826	1.8618	1.4650	0.9262	1.3456	2.4826	1.4650	1.7232	0.6458	1.5700
18	2.8341	1.0222	0.6458	2.4826	1.4650	1.4650	1.1240	0.9271	4.0487	1.7232	1.7232	0.5938	1.6700
19	4.5181	1.0222	0.6458	1.3452	1.4650	1.3452	0.8358	0.7509	3.6014	1.5909	2.4826	1.4650	1.7600
20	3.0204	1.0222	0.6459	1.3452	1.4650	1.4650	0.8358	0.6996	2.4826	1.3452	2.4826	1.3452	1.5100
21	2.6548	1.7232	0.5437	1.8618	1.4650	1.1240	1.0222	1.3452	1.4650	1.1240	2.6548	1.2316	1.5200
22	2.4826	4.0487	0.5437	2.1588	1.4650	1.3452	1.2316	1.1240	2.0070	1.1240	2.6548	1.1240	1.7800
23	2.1588	2.0070	0.4954	1.8618	1.3452	1.3452	0.8358	1.1246	1.7227	1.1240	2.1588	1.0222	1.4300
24	1.7232	1.4650	0.4954	1.7232	1.2321	1.1240	0.8358	0.8358	1.4650	1.0222	1.7232	0.8358	1.2100
25	1.7232	1.1240	0.5437	0.5437	1.2316	1.1240	0.7509	0.8358	2.1573	0.9262	1.4650	0.7509	1.1000
26	1.4650	2.1588	0.5437	1.1240	1.4650	1.2316	0.7509	1.0222	4.2837	1.1240	1.4650	0.6996	1.4400
27	1.4650	1.5909	0.5437	0.8358	1.7232	1.0222	0.7509	1.0222	3.6166	1.1240	1.4650	0.6996	1.3200
28	1.3452	1.4650	0.5437	0.8358	6.2371	1.3456	1.0222	0.8358	1.4650	1.0222	1.3452	0.6458	1.5100
29	1.4650		0.4955	0.6996	1.4650	1.4650	0.8358	0.8358	2.0059	1.1240	1.1240	0.6458	1.1100
30	1.4650		0.4954	0.6458	1.3452	1.7232	0.7509	0.8358	1.5909	1.1240	1.0222	0.5938	1.0500
31	1.4650		0.4955		1.8618		1.4650	0.8358		1.1240		0.6458	1.1300
MIN.	1.1240	0.8358	0.4954	0.4490	0.6458	1.0222	0.6458	0.6996	0.8358	0.9262	0.8358	0.5938	
MAX.	5.6968	4.0487	1.1240	2.4826	6.2371	3.0204	1.4650	2.6548	4.2837	2.4826	2.6548	1.4650	
MEAN	0.5800	0.4000	0.8400	1.1900	0.7900	0.9700	1.6400	1.0200	1.5400	0.7000	0.6400	0.5400	

Summary

		Inflow		OPTION-I			OPTION-II			OPTION-III		
Relationship	Conf.	Stage, m	Flow, cms	Chg.	Stage, m	Flow, cms	Chg.	Stage, m	Flow, cms	Chg.	Stage, m	Flow, cms
Small size fish-spawing habitat	*	33.6	1,957	Neg	30.5	1,540	Neg	29.4	1,401	Neg	29.6	1,425
Big Size Fish Habitat	*	22.8	745	Neg	14.1	328	Neg	10.2	190	Neg	10.9	213
Macroinvertebrate biodiversity	*	65.0	7,380	Neg	62.8	6,964	Neg	62.1	6,825	Neg	55.1	5,537

Index Values

Index	OPTION-I	OPTION-II	OPTION-III
A - Small Fish	-21.3	-28.4	-27.2
B - Big Fish	-55.9	-74.6	-71.5
C - Macroinvertebrate	-5.6	-7.5	-25.0
D -	n/a	n/a	n/a
E -	n/a	n/a	n/a

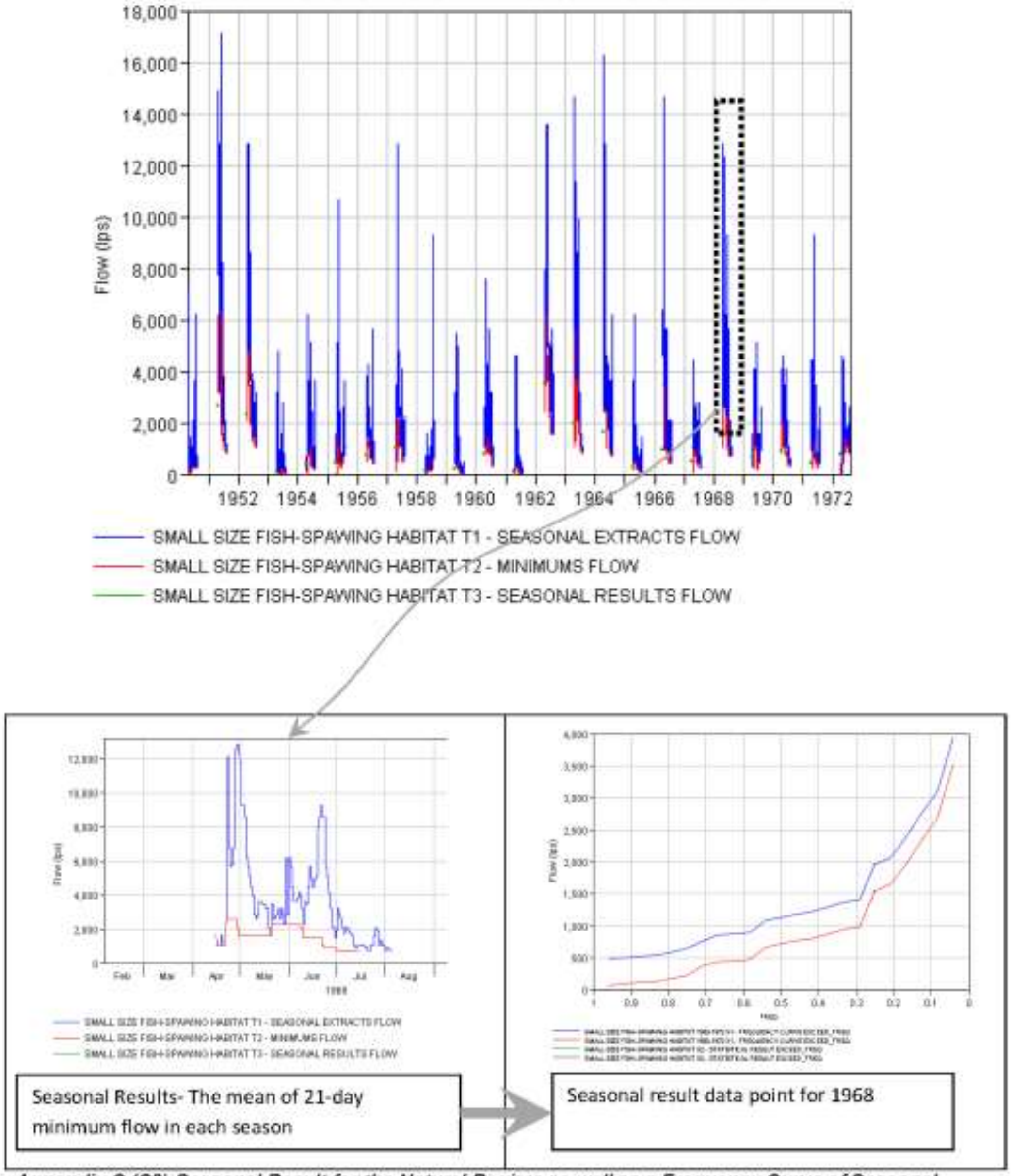
No reverse lookup flow frequency data sets were analyzed.

No reverse lookup flow duration data sets were analyzed.

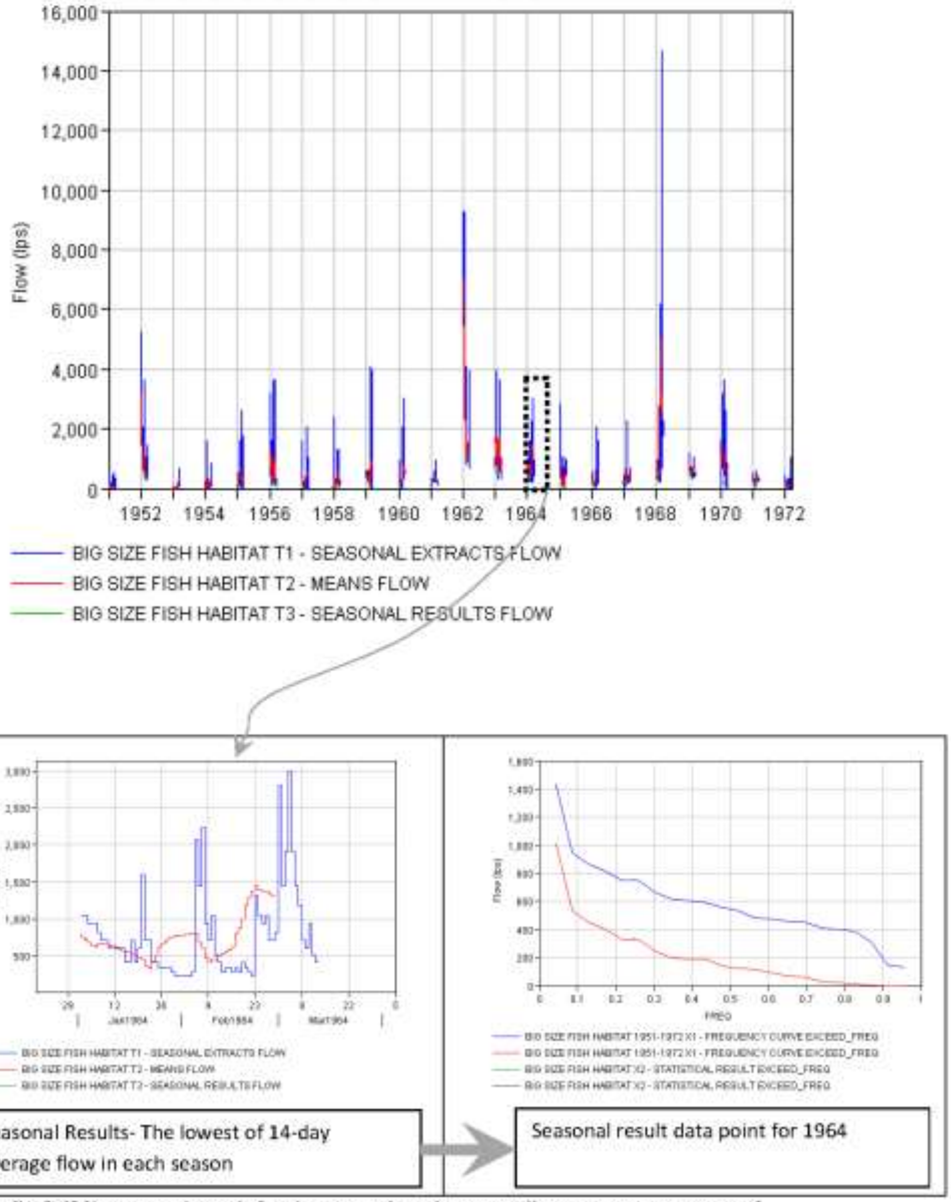
Notes:

(NC: no change)

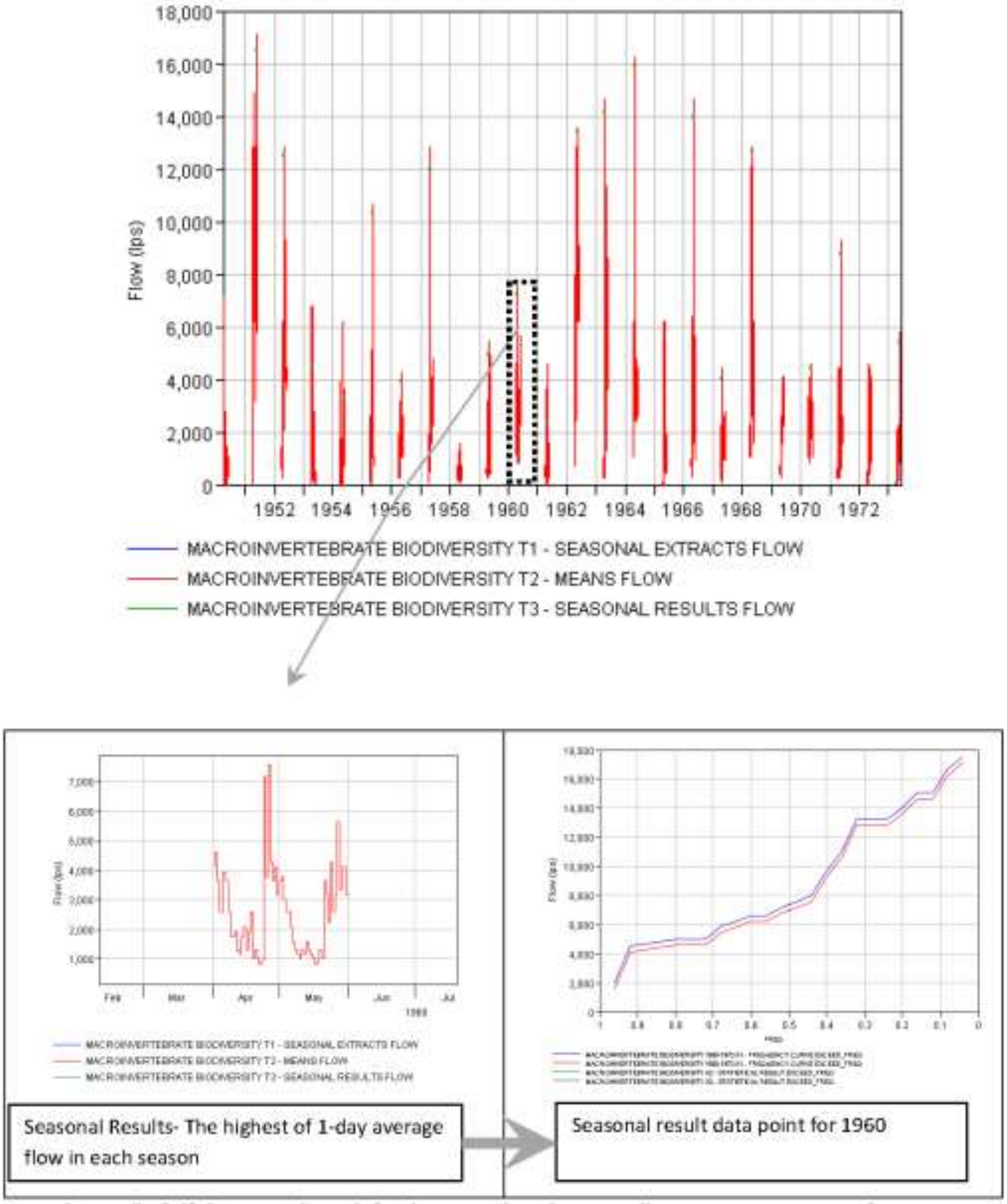
Appendix C (C1): Statistical Result for Simulation, Project Report and Computational output for RIVER SECTION 1-1



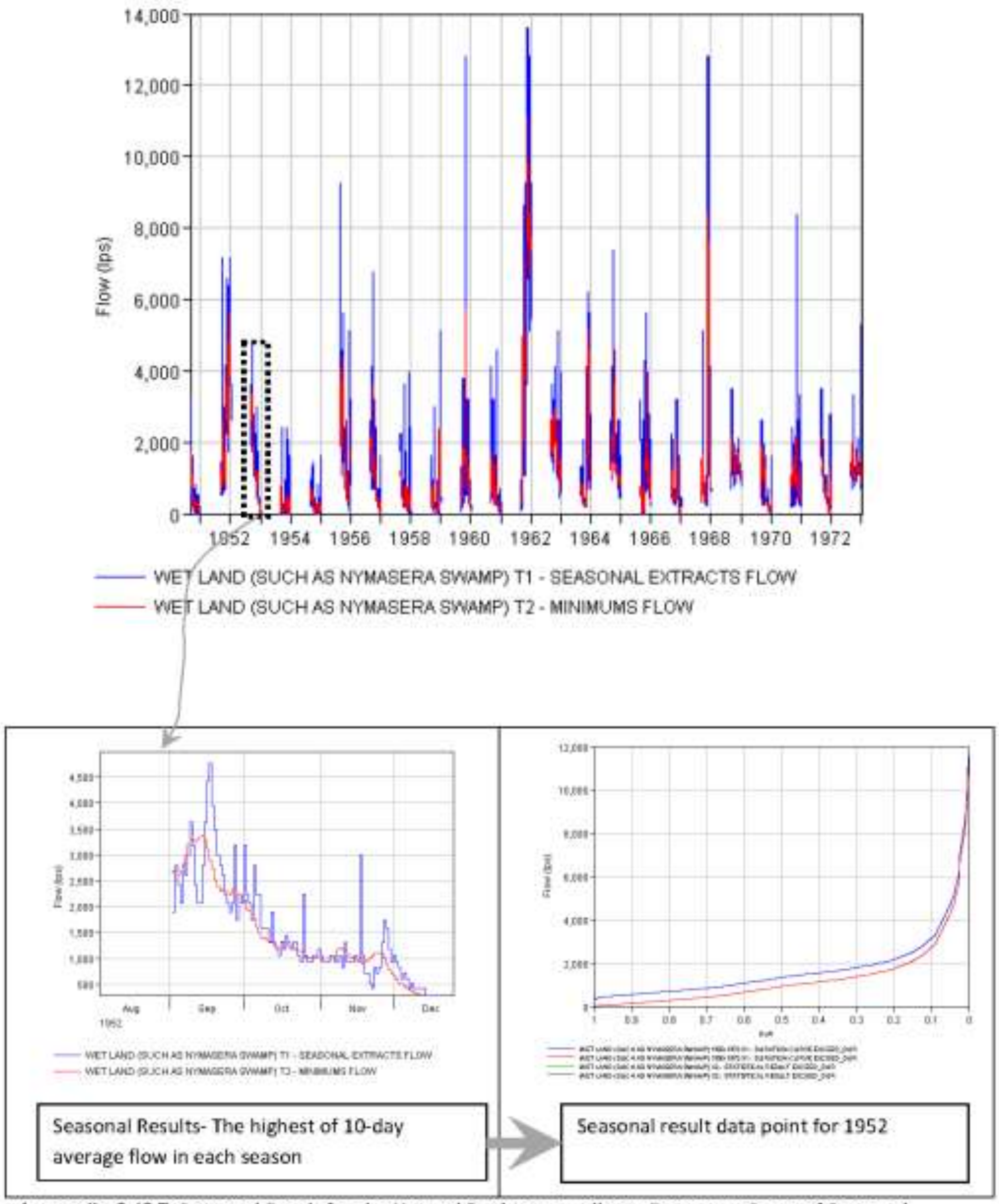
Appendix C (C2):Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for Small Size Fish and Spawning (Option-I and River Section 1-1)



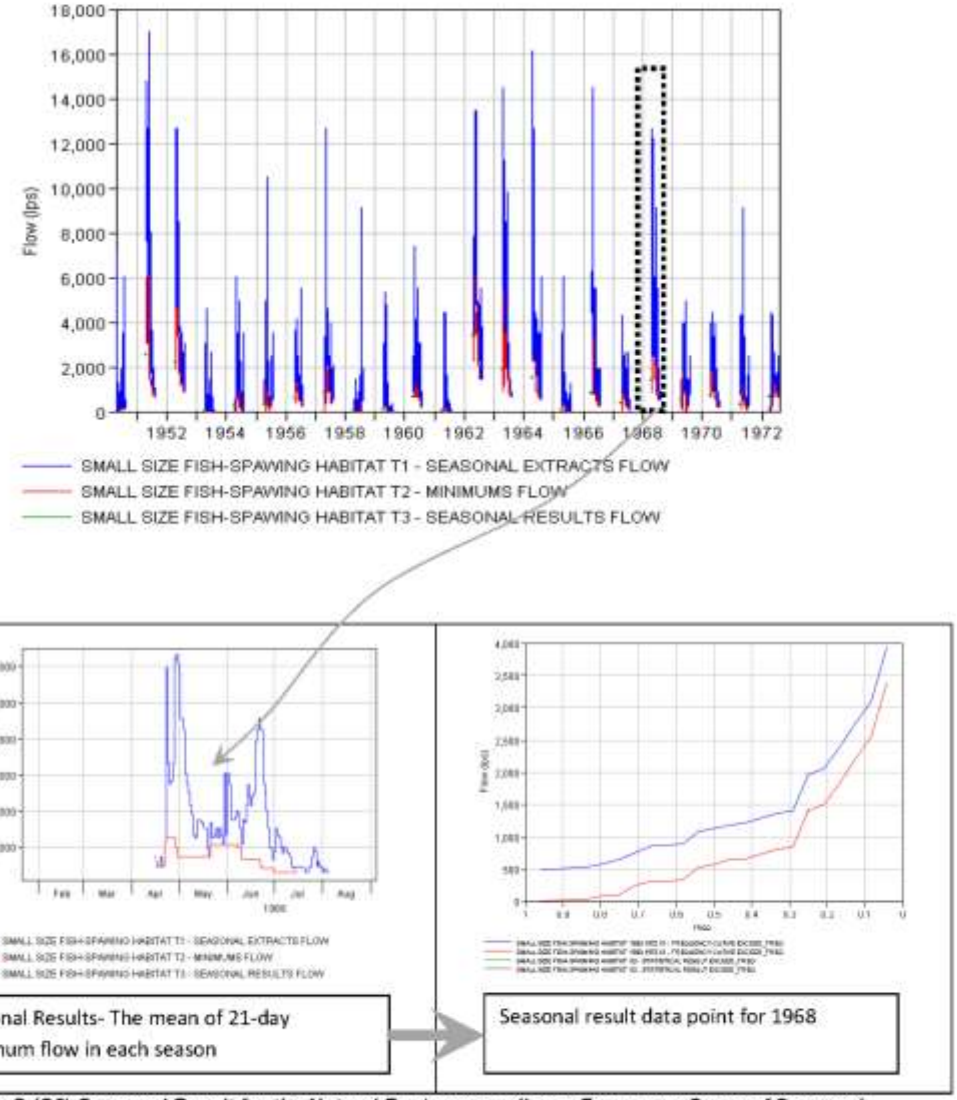
Appendix C (C3):Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for <u>Big Sized Fishes and Rearing</u> (Option-I and River Section 1-1)



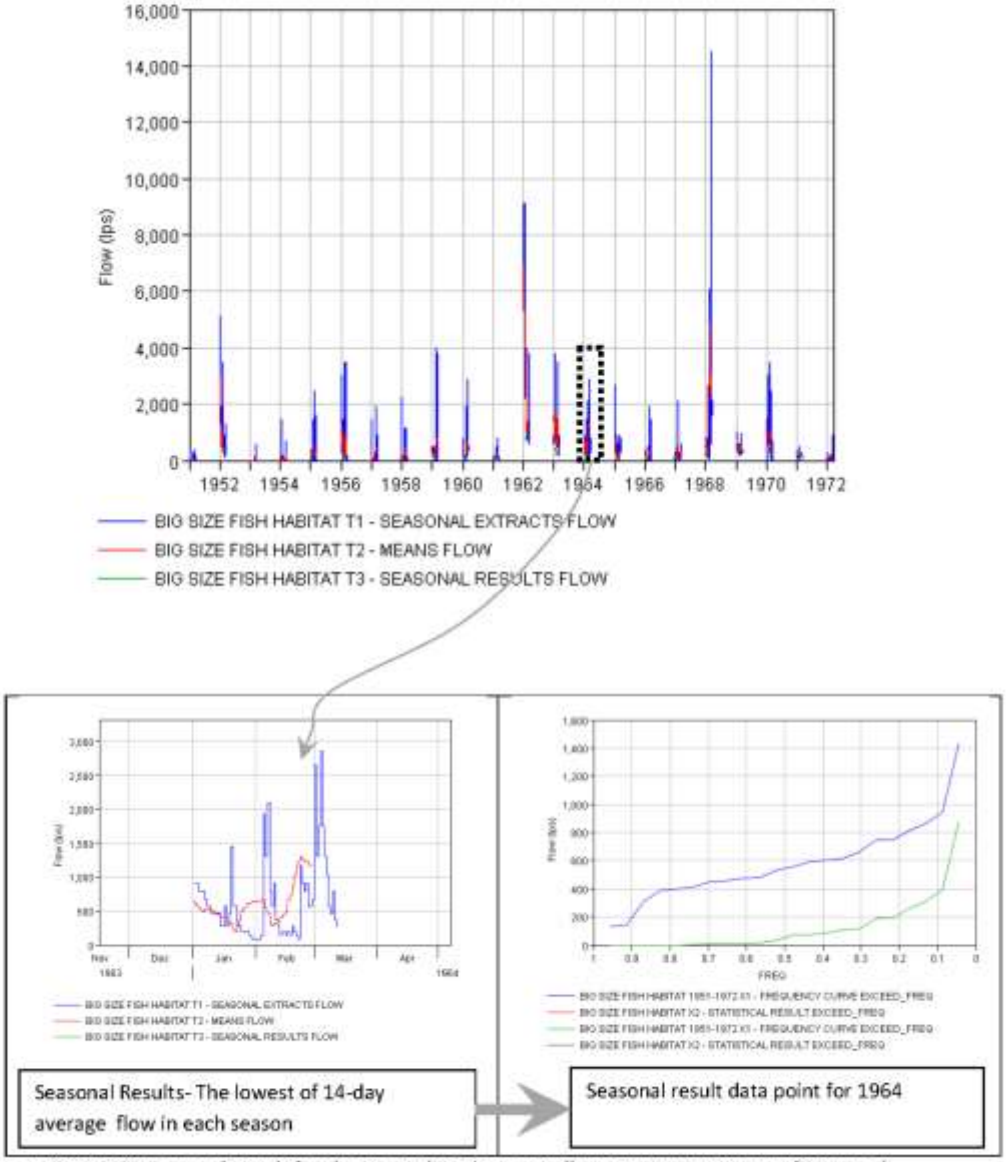
Appendix C (C4):Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for <u>Micro Invertebrate</u> (Option-I and River Section 1-1)



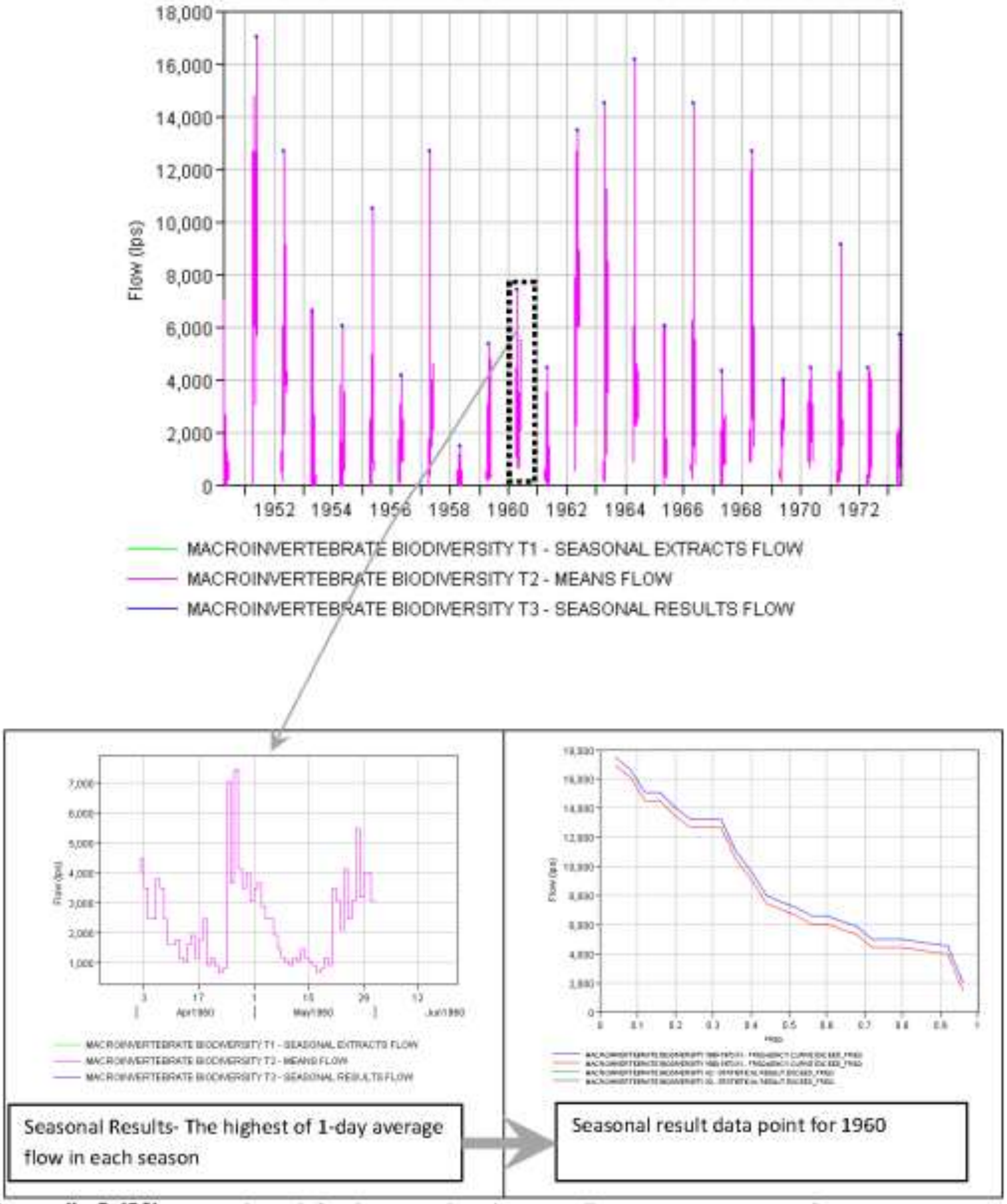
Appendix C (C5):Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for <u>Wetland (Nymasera Swamp)</u> (Option-I and River Section 1-1)



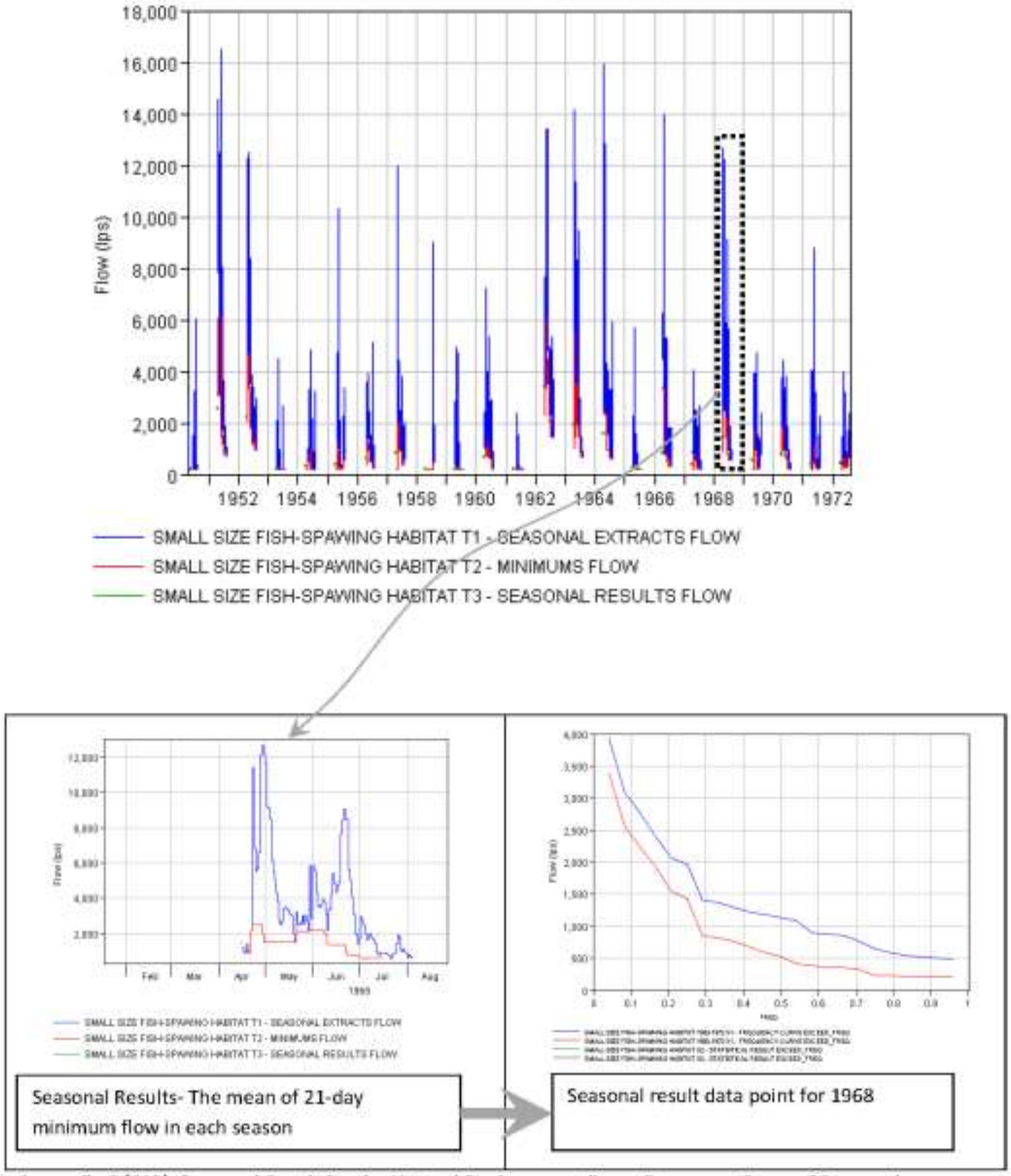
Appendix C (C6):Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for <u>Small Size Fish and Spawning</u> (Option-II and River Section 1-1)



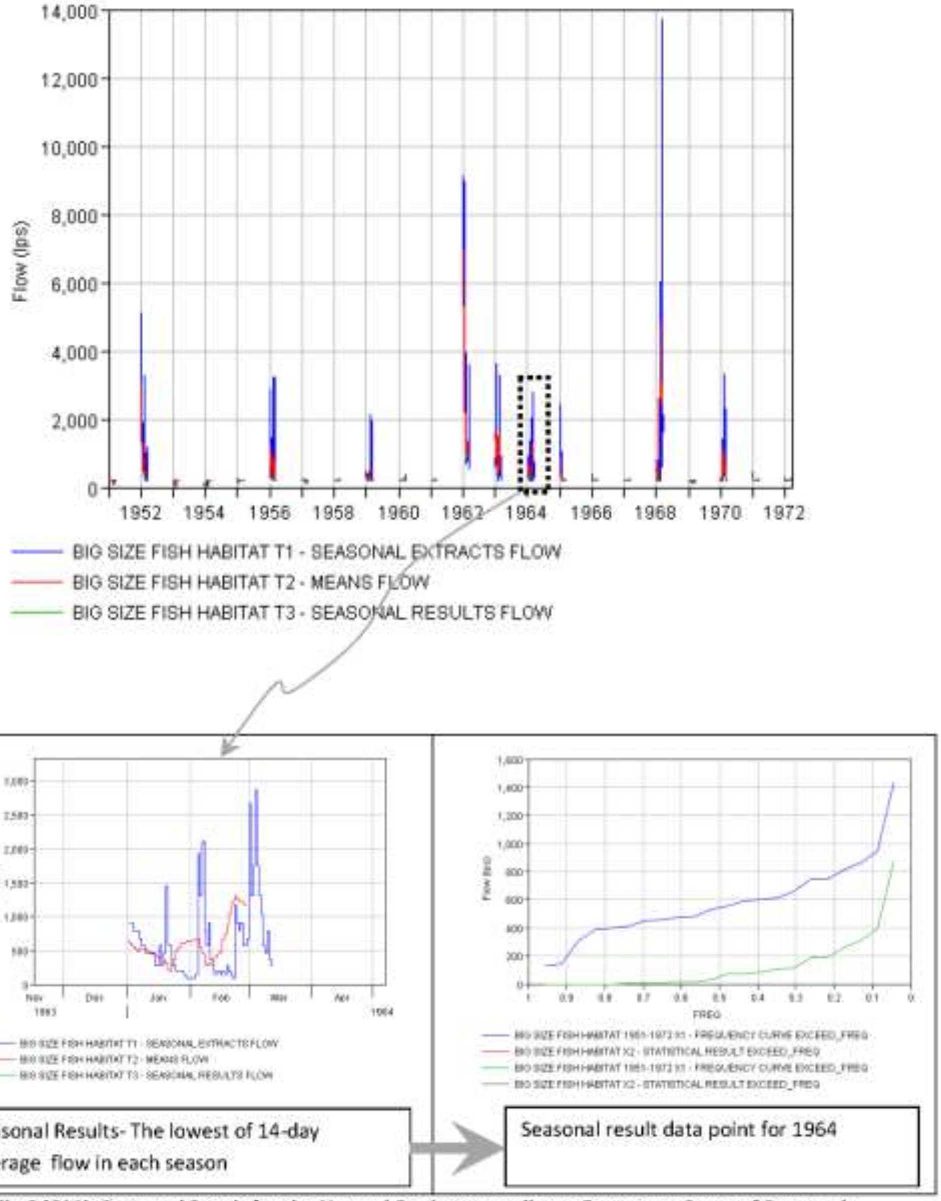
Appendix C (C7):Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for <u>Big Sized Fishes and Rearing</u> (Option-II and River Section 1-1)



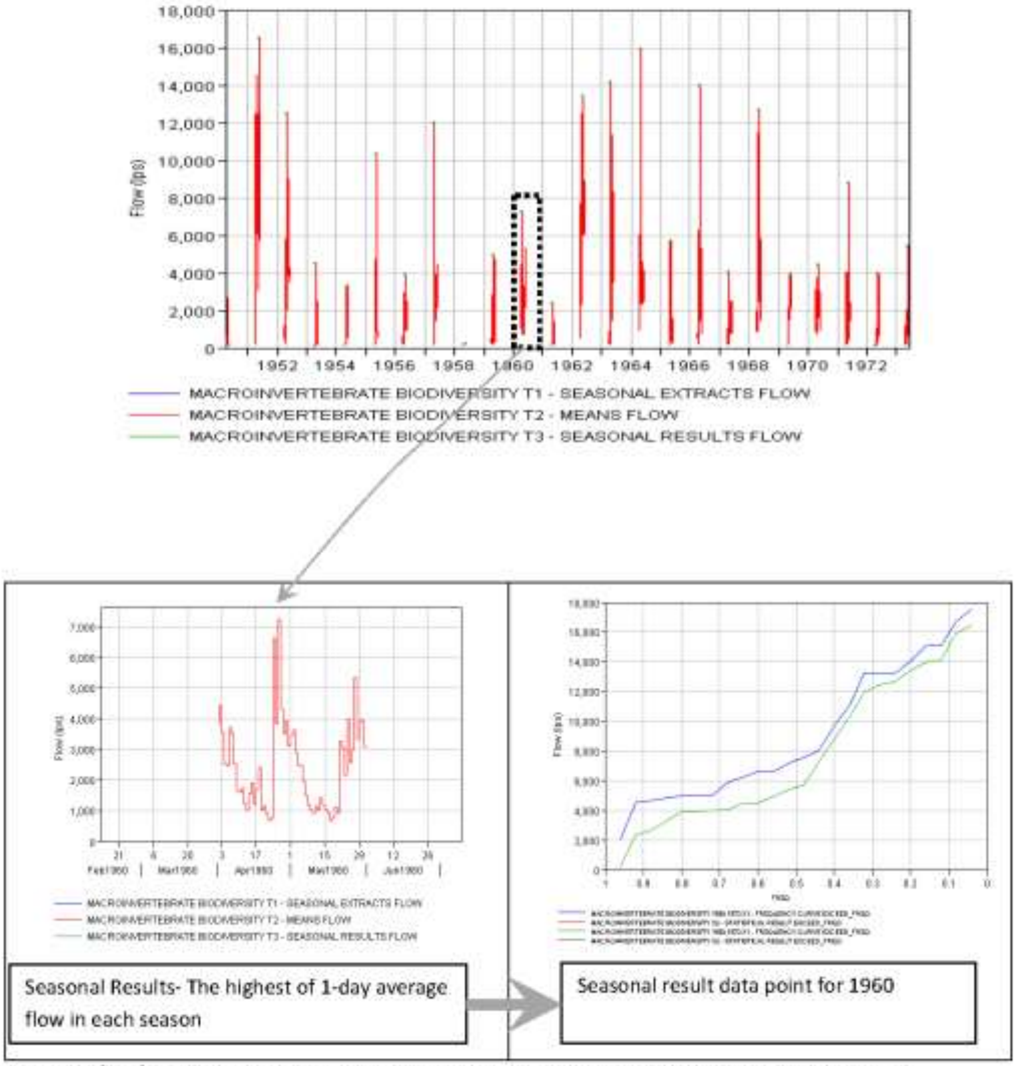
Appendix C (C8):*Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for <u>Micro Invertebrate</u> (Option-II and River Section 1-1)*



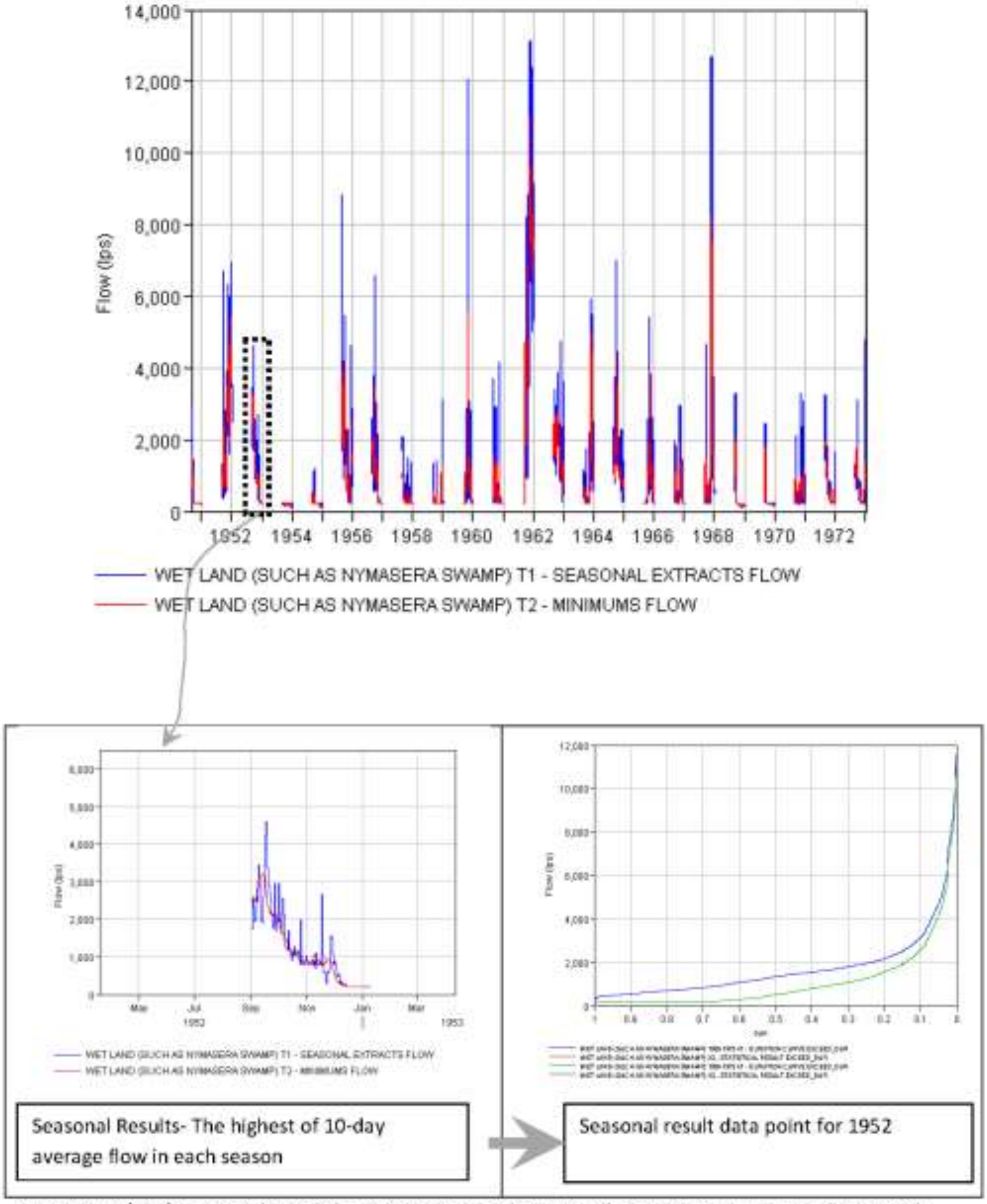
Appendix C (C10): Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for Small Size Fish and Spawning (Option-III and River Section 1-1)



Appendix C (C11): Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for Big Sized Fishes and Rearing (Option-III and River Section 1-1)



Appendix C (C12): Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for Micro Invertebrate (Option-III and River Section 1-1)



Appendix C (C13): Seasonal Result for the Natural Regime as well as a Frequency Curve of Seasonal Results for Natural and Gauged Flow Regimes for Wetland (Nymasera Swamp) (Option-III and River Section 1-1)

Summary

		Inflow		OPTION-I			OPTION-II			OPTION-III	
Relationship	Conf.	Stage, m	Flow, cms	Chg.	Stage, m	Flow, cms	Chg.	Stage, m	Flow, cms	Chg.	Stage, m	Flow, cms
Small size fish-spawing habitat	*	42.7	3,538	Neg	40.5	3,121	Neg	39.8	2,982	Neg	39.9	3,006
Big Size Fish Habitat	*	28.9	1,347	Neg	25.0	930	Neg	23.4	792	Neg	23.9	828
Macroinvertebrate biodiversity	*	91.4	13,343	Neg	89.7	12,927	Neg	89.2	12,788	Neg	80.6	10,727
Wet Land (such as Nymasera Swamp)	*	39.2	2,883	Neg	36.8	2,467	Neg	36.0	2,328	Neg	35.3	2,203

Index Values

Index	OPTION-I	OPTION-II	OPTION-III
-	-11.8	-15.7	-15.0
-	-30.9	-41.2	-38.5
-	-3.1	-4.2	-19.6
-	-14.5	-19.3	-23.6
-	n/a	n/a	n/a

No reverse lookup flow frequency data sets were analyzed.

Reverse Look-ups - Flow Duration

		Inflow	OPTION-I		OPTION-II		OPTION-III	
Relationship	Conf.	% X, of time	Chg.	% X, of time	Chg.	% X, of time	Chg.	% X, of time
Wetland health reverse lookup	*	97.7	Neg	88.4	Neg	84.6	Neg	97.3

Appendix C (C14): Statistical Result for Simulation, Project Report and Computational output for RIVER SECTION 6-6 (Note Stage (cm) and Flow (lps)