CPWF Project Report

Improved Planning of Large Dam Operation: Using Decision Support Systems to Optimize Livelihood Benefits, Safeguard Health and Protect the Environment

Project Number PN36

Matthew McCartney
IWMI

for submission to the

CGIAR Challenge Program on
WATER & FOOD

December, 2009

Acknowledgements

This report synthesizes findings from the project "*Improved planning of large dam operation: using decision support systems to optimize livelihood benefits, safeguard health and protect the environment*". This project was a collaboration of the following three institutions:

Addis-Ababa University, Addis Ababa, Ethiopia

Southern Waters, Cape Town, South Africa

International Water Management Institute (IWMI), Regional office for the Nile Basin and East Africa, Addis Ababa, Ethiopia

A large number of people contributed in a wide range of ways to the different components of the study. The following are due a special word of thanks: Solomon Kibret, Yilma Seleshi, Dereje Hailu, Beyene Petros, Asegid Taye, Ayalew Gebre and Derese Getachew of Addis Abba University; Jackie King of Southern Waters; Seleshi Bekele Awulachew, Eline Boelee, Solomon Seyoum and Jonathan Lautze of IWMI; Tesfaye Abebe, Lemma Regassa and Dereje Olana of Oromia Regional Health Bureau; Michael Abebe of the Ministry of Water Resources; Wondie Ayalew of Bahar Dar University; Bruce Paxton of the University of Cape Town; Paul Kirshen of Tufts University; Richard Pollack and the late Andrew Spielman of the Harvard School of Public Health.

A number of postgraduate students contributed to the project through research conducted for their theses: Jonathan Lautze, Benon Zaake, Getachew Daniel, Abeyu Shiferaw, Wubneh Abebe, Tadesse Alemayehu, Yordanos Gebremeskel, Berhan Mellese, Amelework Tesfaye and Julia Reis.

The Ethiopian Electric Power Corporation, the Ethiopian Federal Ministry of Water Resources, the Ethiopian National Meteorological Agency, the Ethiopian Federal Ministry of Health, the Oromia Health Bureau and the Ethiopian Central Statistics Authority all provided invaluable data.

Program Preface

The Challenge Program on Water and Food (CPWF) contributes to efforts of the international community to ensure global diversions of water to agriculture are maintained at the level of the year 2000. It is a multi-institutional research initiative that aims to increase water productivity for agriculture—that is, to change the way water is managed and used to meet international food security and poverty eradication goals—in order to leave more water for other users and the environment.

The CPWF conducts action-oriented research in nine river basins in Africa, Asia and Latin America, focusing on crop water productivity, fisheries and aquatic ecosystems, community arrangements for sharing water, integrated river basin management, and institutions and policies for successful implementation of developments in the water-food-environment nexus.

Project Preface

Improved Planning of Large Dam Operation: Using Decision Support Systems to Optimize Livelihood Benefits, Safeguard Health and Protect the Environment. This project was undertaken with the aim of providing information to assist policy-makers, water resource managers and other interested stakeholders in the planning and management of large dams in Africa. The project highlighted the importance of considering environmental and social (including health) issues in dam planning and operation and illustrated how contemporary Decision Support Systems can be used to assist decision making processes. Key project findings relate to: i) the importance of stakeholder involvement in decision-making and how to enhance it; ii) the effectiveness of EIA follow-up; iii) the malaria implications of large dam construction; iv) the simulation of environmental impacts of large dam development and v) estimates of environmental flows. Guidelines on the use of DSS for key aspects of dam planning and operation have been developed.

CPWF Project Report Series

Each report in the CPWF Project Report series is reviewed internally by CPWF staff and researchers. The reports are published and distributed both in hard copy and electronically at www.waterandfood.org. Reports may be copied freely and cited with due acknowledgment. Before taking any action based on the information in this publication, readers are advised to seek expert professional, scientific and technical advice.

McCartney, M.P. 2009. *Improved Planning of Large Dam Operation: Using Decision Support Systems to Optimize Livelihood Benefits, Safeguard Health and Protect the Environment*. Colombo, Sri Lanka: Challenge Program for Water and Food 76 pp. (CPWF Project Report Series).

CONTENTS

LIST OF TABLES

LIST OF FIGURES

RESEARCH HIGHLIGHTS

In Africa, relatively few large dams have been built but, because of the urgent need for economic development, many new dams are currently under construction and many more are planned for the near future. However, the livelihoods of large numbers of people are dependent on natural resources and agriculture, both of which may be adversely affected by large dams. Furthermore, the requirements for dams vary both between different stakeholders and over time. Consequently, the planning and operation of large dams requires consideration of many complex and inter-related issues and poses intricate technical and political problems. Under such circumstances decision-making is extremely difficult.

The primary objective of this study was to investigate the applicability of using contemporary decision support systems (DSSs) to improve dam planning and operation through better inclusion of environmental and social (including health) issues in decision-making processes. The research was undertaken primarily in the Nile Basin through a number of case studies. Research highlights include:

- The most detailed study to date on the likely impact of large dam construction (for irrigation and hydropower) in the Lake Tana catchment on lake levels and the possible environmental and social consequences (Ethiopia).
- The use of value trees to identify and prioritize key stakeholder concerns in the development and operation of dams on the Equatorial Nile (Uganda).
- What is believed to be the first ever attempt to determine environmental flows in the Blue Nile, specifically in the reach containing the world famous Tis Issat Falls, affected by flow regulation and upstream abstraction for hydropower (Ethiopia).
- One of the few studies conducted in Africa to ascertain different stakeholder perceptions of decision-making processes in relation to dam operation and a rare evaluation of compensation measures related to dam construction (Ethiopia).
- One of the first studies ever to evaluate the effectiveness of follow-up to an Environmental Impact Assessment (EIA) conducted prior to construction of a large dam in Ethiopia.
- One of the few studies conducted in Africa that quantified the impact of a large dam on malaria transmission and highlighted the possibility of using dam operation as a mitigation measure (Ethiopia).

Using lessons learned from these case studies, in conjunction with additional information from other sources and discussion at project workshops, practitioner guidelines on the contribution that DSSs can make to key issues in decision-making related to dam planning and operation in Africa, have been developed.

EXECUTIVE SUMMARY

Large dams bring the challenges of sustainable development, and specifically integrated water resources management, to the fore. By storing water, and so increasing options for water management, large dams have brought broad social and economic benefits and have made significant contributions to national and regional development. However, history shows that dams can have profound social and economic repercussions for those, invariably poor, people living close to or downstream from them. Such communities often have limited livelihood options and so are particularly vulnerable to changes in the condition of the natural resources on which they depend. Too often in the past the adverse impacts experienced by these communities have been largely ignored and, as a result, far too many people have had to "*pay the price of development".*

It is now widely acknowledged that a key goal of any large dam must be to ensure that it provides a development opportunity for *all*. This includes those communities living close to the dam who may be displaced or whose livelihoods may be disrupted. This requires that dams are planned and operated in a different way to the past, with much greater emphasis on local needs. This in turn requires that environmental and social factors are considered in much greater detail than was typically the case in the past.

Planning and operating large dams is extremely difficult. Complexity is manifest in uncertainty arising from climate variability and hence river flows, the intricacy of biophysical interactions within riverine ecosystems and, perhaps most significantly, in the number and kind of stakeholders involved. That is, stakeholders with different and often conflicting interests, values or rights; with incompatible forms of knowledge, social norms and attitudes; with unequal power and influence. Hence, decision-making in relation to large dam planning and operation is a far from trivial task.

In recent years a large number of Decision Support Systems (DSSs) have been developed to assist decision-makers to improve dam planning and operation. This project comprised a multi-disciplinary study which investigated the use of DSSs in dam planning and operation and specifically the importance of improved evaluation of environmental and social issues in decision-making processes. Although an original intention of the project was to identify the DSSs most appropriate for the complexity of large dam planning and operation, this proved to be an unrealistic objective. It is impractical because there are a huge number of DSSs and an even greater variety of situations in which they can be used. Consequently, any given DSS will be appropriate to assist decision-making in certain situations but completely inappropriate in others. The DSSs used in this study were selected based on the issues being investigated, the data available and the technical capacity and preferences of those involved.

The project was conducted using case studies in Ethiopia and Uganda, undertaken to evaluate different issues in decision-making processes related to large dam projects. This report:

- Synthesizes the key findings of the project
- Provides a brief evaluation of the outcomes and impacts of the project
- Summarizes key recommendations

The key generic recommendations from the project are:

Options assessment: Comprehensive options assessment of dams and their alternatives is critical for sustainable development. In any given situation, development needs should be matched to the most appropriate development options. Hence, before a dam is built a "needs assessment" should be conducted and a dam (or dams) must be identified as the most feasible/beneficial option. Clearly a comprehensive assessment requires a

detailed evaluation of the implications (both positive and negative) of different options for fulfilling needs. DSSs can contribute to options assessment both by assisting in the identification of needs (across a range of scales) and by providing information on the likely consequences of a range of approaches to satisfy the identified needs. At the national level DSSs can also provide information to assist with the establishment of goals, policies and procedures that facilitate proper options assessment. Where dams are being considered DSSs can contribute to the options assessment by investigating their impact both individually and cumulatively within a catchment.

Social issues: The concerns relating to large dams are complex, encompassing many interlinked social, economic and ecological dimensions. The social complexity of such schemes requires that social components should be given as much, or even greater, consideration than technical aspects in project planning. To minimize unwarranted social stress, requires that all stakeholders understand the scheme and participate in decision-making from an early stage. DSSs can contribute to this process by identifying the social implications of biophysical changes arising from dam construction and operation. To empower stakeholders in negotiating processes DSSs need to provide and present information that is understandable to a range of stakeholders, including non-technical people.

Implementation of EIA: Successful implementation of EIA recommendations requires that both policies and institutions are in place to enable adequate follow-up. It also requires that project managers have the tools necessary to facilitate the effective monitoring of impacts and to predict the potential consequences of changes arising from dam construction and operation. DSSs can help with determining possible differences in outcomes and impacts arising from different scenarios of development or different modes of operation of a dam. DSSs can also help improve follow-up mechanisms by, amongst other things, providing dam operators with tools to assist in the archiving, analyses and interpretation of data collected in monitoring networks established through EIAs. The intention is to provide insights into how the system (including social components) are being impacted by a dam and to facilitate informed decision-making to enable adjustments to be made in the way it is operated.

Environmental Flows: Environmental flows are essential for the sustainable and equitable development of aquatic resources. The broad impacts of flow regime changes caused by dams are now reasonably well understood. However, all dams are unique and there is often great uncertainty of specific impacts and in particular the likely socio-economic implications of change. DSSs are increasingly being combined with expert judgment to gain insights into flow-ecosystem links and in turn the links to livelihoods. The countries of sub-Saharan Africa would benefit significantly from programs to build capacity in environmental flow assessment. As a starting point, these should be developed using the expert opinion of national ecologists, hydrologist, social scientists and others who have detailed knowledge and experience of the region's rivers, with guidance from experts in the process of environmental flow assessment. Such programs should include research to better understand flow-ecology-livelihood links as well as how to proceed with limited knowledge and improve relevant DSSs. Even if the initial results are uncertain, attempting environmental flow assessment, utilizing teams of appropriately guided experts, would facilitate holistic approaches and assist interactions between different disciplines. This would be a useful first step in the development of national and regional expertise in environmental flow assessment.

Health impacts: In Africa there are strong links between disease and the construction of infrastructure, including dams. However, the health impacts arising from the construction and operation of dams are often poorly understood and often overlooked during dam planning and operation. DSSs can contribute significantly to both improved understanding of the complex links between disease vectors and reservoirs and also better management of likely health impacts. Many models have been developed that simulate the mechanisms underlying disease vector dynamics and their relations to the environment. Although much research still needs to be undertaken, these models enable a better understanding of the mechanisms underlying disease transmission both generally and also in specific geographic environments. As such they provide a starting point for predicting the likely impacts prior to dam construction and the impacts that may arise from specific interventions to reduce transmission. By quantifying the likely health impacts, DSSs can contribute to Health Impact Assessments (HIAs) which provide a systematic approach for screening, assessing, appraising and formulating management plans to address key public health issues associated with large dams. However, while most African countries have a framework for EIAs few possess adequate capacity for HIAs. A policy shift is required to build capacity and ensure that institutions promote integrated Environmental Health Impact Assessments rather than simple EIA.

Benefit sharing: Too often, in project planning and implementation, the national interest has been the primary consideration and local concerns have been neglected. Ensuring equitable outcomes from development requires that measures are developed to sufficiently off-set any negative impacts. To design adequate benefit sharing mechanisms understanding of local conditions and good data are essential. In the past even where social baselines have been established data on living standards linked to livelihoods are often missing. As a result, it is impossible to determine whether living standards have been restored or improved in the great majority of projects. This is a serious omission which hinders the implementation of remedial measures and ultimately undermines evaluations of the extent to which projects are a success. Post project evaluation of the success/failure of compensation and benefit sharing mechanisms are very rare. However, past experience shows that in cases where compensation packages were negotiated with project affected communities the process has resulted in better outcomes. Even when, for whatever reason, the negotiated form of compensation proves not to be the most appropriate or effective option, project affected people tend to feel more satisfied, as a result of the negotiation process.

Transboundary waters: Africa is a continent with a large number of rivers that cross international borders, so called "transboundary" rivers. Decisions pertaining to large dam planning and operation made by individual states within transboundary basins are rarely equitable nor, when viewed from the perspective of the entire basin, as effective or efficient as they could be. The challenges in developing DSSs that will be accepted by all the riparian states are manifold. However, when they can be implemented within an appropriate institutional framework, they have an important role to play in building confidence, enhancing cooperation and maximizing the multiple benefits that can be generated within a basin.

INTRODUCTION

In its report, the World Commission on Dams (WCD) called for the inclusion of all identified stakeholders in the planning and management of water resources stored in reservoirs and a more equitable distribution of the benefits to be gained from dams (WCD, 2000). This requires a new approach to the planning and management of large dams.

In Africa, relatively few large dams[1] have been built and many countries have extremely low per capita storage compared to elsewhere in the world (IHA, 2009). Although the need for economic development is urgent, many people continue to rely on natural resources and agriculture, both of which may be adversely affected by large dam construction, to sustain their livelihoods. Consequently, assessing all the implications of dams, both positive and negative, is of paramount importance both when planning new dams and when revising the design or operating rules of existing ones.

Currently the World Bank, the African Development Bank, the New Partnership for African Development (NEPAD) and other influential institutions are advocating increased development of large dams on the African continent. The current position of the World Bank is that major water resource projects provide the basis for broad regional development, with "significant direct and indirect benefits for poor people" (World Bank, 2004). As a result, many dams are being built and many more are planned for the near future (McCartney and King, submitted).

Against this background, the key challenge is to ensure that dams contribute to attempts to obtain reliable and sustainable sources of water, food and energy, whilst avoiding the mistakes of the past. This means placing greater emphasis on issues of equity and minimizing the negative environmental and social impacts.

To maximize the benefits to be obtained from them, dam planners and managers need to take into account a range of inter-linked biophysical, economic, political, organizational, social and environmental factors (Figure 1). However, in any given situation the relationships between these different factors are often extremely complex and not well understood. Many complex issues must be considered and this makes informed decision-making very difficult. In such situations, Decision Support Systems (DSSs) can improve the effectiveness of decision-making processes by helping to identify and solve problems.

The environmental and social impacts of dams need to be considered in tandem because they are strongly linked; many social changes arise as a consequence of environmental changes, for example, through impacts on natural resources (King and McCartney, 2007). A key reason why historically the intended outcomes of large dams have often not been fully realized is because environmental and social problems have rarely been given adequate consideration in project planning and implementation.

[1] Large dams are defined as dams greater than 15m in height from base to crest or storage capacity exceeding 3 million cubic meters for heights between 5 and 15m (ICOLD, 2003).

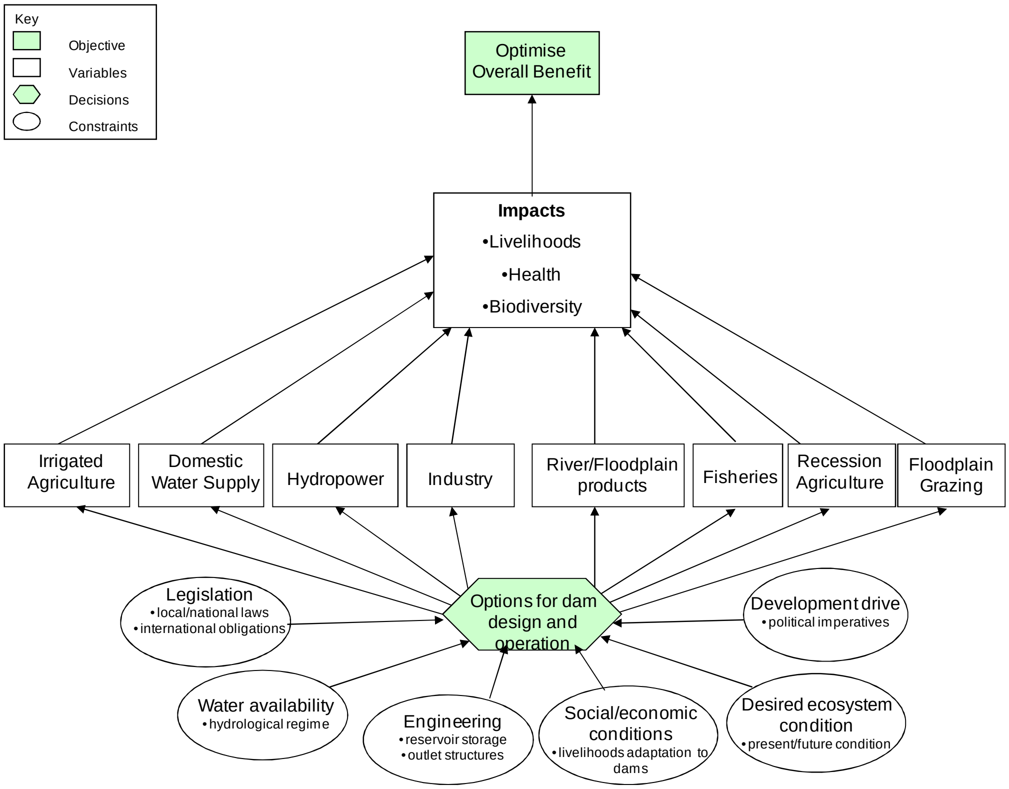


Figure 1. Complex web of interlinked issues and trade-offs that must be taken into account in planning dam design and operation

PROJECT OBJECTIVES

As described in the project proposal, the primary objectives of this study were to:

- demonstrate the value of modern DSS in enhancing the management of water resources stored in large reservoirs.
- strengthen national and regional capacity in the use of modern DSS for dam planning and operation.

The first of these was achieved by investigating how environmental and social issues could be better incorporated in decision-making processes related to large dam planning and operation and to highlight how contemporary Decision Support Systems (DSSs) could be used for this purpose. To fulfill this objective, the primary output, envisaged in the project proposal, was practitioner guidelines on the use of (DSSs) to improve key aspects of dam planning and management.

In addition to the guidelines, the second was achieved largely through the training of MSc and PhD students, but also through workshops and other fora, in which staff of national and regional institutions, including academics, water resource managers and dam operators, participated. In these forums the difficulties of incorporating social and environmental issues and the role of DSSs in dam planning and management were discussed.

The project investigated different aspects of decision-making processes in relation to dam planning and operation in Africa, specifically in light of the recommendations made by both the World Commission on Dams (WCD, 2000) and the Dams Development Project (UNEP, 2007). The work undertaken, through a number of case studies, targeted the following aspects of large dam management:

- stakeholder involvement in the decision-making processes related to large dam planning and operation in Ethiopia.
- enhancement of stakeholder participation in regulation studies of the Equatorial Nile.
- the effectiveness of EIA follow-up after large dam construction in Ethiopia.
- the malaria implications of large dam construction and the possibility of using dam operation as a tool for mitigation in Ethiopia.
- how DSSs can be used to provide preliminary estimates of environmental flows in data scarce regions in Ethiopia.
- how DSSs can be used to evaluate the environmental impacts of planned large dam construction in Ethiopia.

The case studies undertaken provided insight into decision-making processes and enabled several DSSs to be used. On the basis of experience gained through the case studies, and more generally, the guidelines have been developed (McCartney and King, submitted). These are intended to inform policy-makers, water resource managers and other interested stakeholders about the contribution DSSs can make to several key aspects of dam planning and operation.

For ease of reporting each of the areas identified is reported as a separate project objective, in the following.

1 Objective 1: To highlight the importance of stakeholder involvement in decision-making processes related to large dam planning and operation

1.1 Background

Lake Tana is valuable for many thousands of people, including the communities who live around the lakeshore, those living on islands and close to the Blue Nile River, which flows from it. As part of the Government of Ethiopia's strategy for economic development, the Lake Tana catchment (Figure 1.1) has been identified as a region with high priority for significant infrastructure investment and related development. Currently the water resources of the catchment are largely unexploited. At present there is a single dam at the outlet of the lake, called the Chara Chara Weir[2]. This regulates outflow from the lake for downstream hydropower generation. The intention is, in future, to stimulate economic growth and reduce poverty through the construction of additional infrastructure, specifically hydropower and irrigation schemes (MoFED, 2006). To this end, the Tana and adjacent Beles catchment have been identified as one of five "growth corridors" in the country and an integrated water resources development plan is being implemented (Jagannathan and Abebe, in press).

In this case study we conducted stakeholder surveys to assess the opinions, interests and concerns of various stakeholders, in relation to both past water infrastructure development (i.e., the Chara Chara weir) and current infrastructure development (i.e., the Koga dam) (Table 1.1). The specific aims of the stakeholder surveys for both schemes were to:

- Identify key stakeholders
- Ascertain the main issues of concern for each stakeholder group;
- Determine potential areas of difference in the way different stakeholders would like the infrastructure operated;
- Ascertain the procedures for decision-making in relation to weir operation for the Chara Chara weir and in relation to compensation for the Koga dam);
- Determine the current and future procedures for dealing with issues of public (and other stakeholders) concern over dam operation and how effective these are.

[2] Although called the Chara Chara "Weir" by international definitions the structure at the outlet of Lake Tana constitutes a large dam since it stores more than 3 Mm^3 of water (ICOLD, 2003).

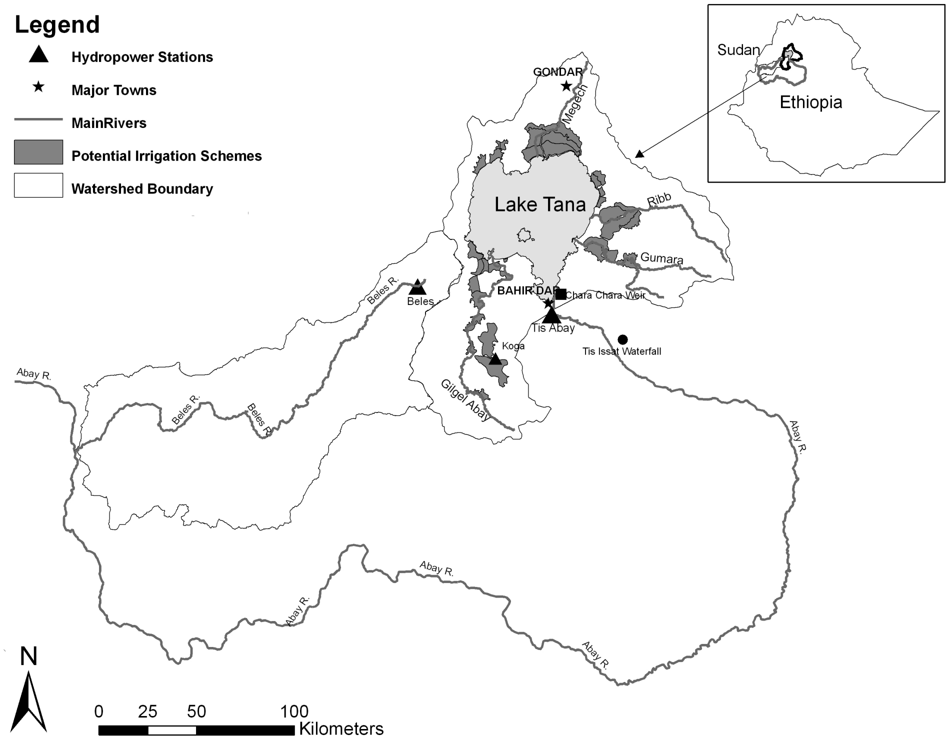


Figure 1.1. Map of the Lake Tana catchment, showing Koga dam and Chara Char weir as well as planned irrigation schemes.

Table 1.1. Summary details of the Chara Chara weir and Koga dam

Scheme	Date of construction	Purpose
Chara Chara weir	1995 with additional gates added in 2001	Regulation of outflow from Lake Tana for downstream diversion to the Tis Abay hydroelectric power stations (Tis Abay I and II), located 35km downstream of the dam. These two stations have an installed capacity of 72 MW, 9% of the total grid-based generating capacity of the country (814 MW). The dam is managed by the Ethiopian Electric Power Corporation (EEPCo).
Koga dam and irrigation scheme	Dam completed in 2008*. Irrigation scheme still under construction	Water storage on the Koga river (an inflowing tributary to Lake Tana) to provide water for the Koga smallholder irrigation scheme (7,000 ha). A watershed management component was included in the project to reduce sediment inflows to the reservoir. The project is managed by a "project office" with a cooperative established to safeguard local community interests.

* the stakeholder survey was conducted in 2007, prior to completion of the dam

1.2 Methods

Stakeholder analyses were conducted for both the Chara Chara weir and the Koga irrigation scheme. Being essentially a qualitative study, these were conducted by employing the following data gathering instruments:

- Conversational interviews were carried out with systematically selected individual stakeholders representing local communities, groups, and institutions. This technique was employed to capture the views and perspectives of individuals representing different government and private stakeholder organizations on particular topics, which they might be reluctant to disclose in group situations.

- Focus group discussions (FGD) were conducted with 4-7 people. For the Chara Chara weir these included people residing around the lake shore, on the lake islands, and downstream of the Chara Chara weir. These include sample persons representing the farming communities, fishers, and the Negede (an occupational minority group). For the Koga dam these included people from the various farming communities, affected by the project in different ways.

The scientific validity and effectiveness of these methods for assessing social processes is widely recognized (Pretty, 1995). Lists of people interviewed and participating in the focus group discussions are presented in the stakeholder survey reports (Gebre et al. 2007a,b). In both cases stakeholders were divided into three groups (Table 1.2):

1) Primary stakeholders. For the Chara Chara weir, these are people who are directly affected on a daily basis by the operation of the dam. For the Koga dam this group included people who have been, or will be, directly affected by construction of the dam and/or the irrigation scheme.

2) Secondary stakeholders. For the Chara Chara weir, this group comprised organizations that directly represent the interests of the primary stakeholders. For the Koga scheme this group comprised a local cooperative and local administration as well as the scheme management and farmers in communities adjacent to the scheme, but not directly impacted by it.

3) Tertiary stakeholders. For both the Chara Chara weir and the Koga scheme this group comprised regional government departments that make policies and decisions that affect the livelihoods of people living in the area. For the Chara Chara weir, local research institutes, conducting research on the lake and its vicinity, were also included.

Table 1.2. Institutions in each stakeholder category for the Chara Char weir and the Koga dam

	Chara Chara weir	Koga dam and irrigation scheme
Primary stakeholders	i) farmers living upstream of the dam, in close proximity to the shore of the lake, as well as those living close to the river downstream of the dam, between it and the Tis Abay power stations. ii) fishers comprising both artisanal fishers utilizing reed boats as well as commercial fishers utilizing motorized boats. iii) papyrus boat builders – the Negede. iv) the Ethiopian Electric and Power Corporation (EEPCo) responsible for day to day operation of the dam. v) private enterprises with a vested interest in tourism, including hotels and the operators of tour boats	i) farmers displaced by the dam and resettled ii) farmers waiting to be displaced iii) communities having to host resettled farmers
Secondary stakeholders	i) the Lake Tana Transport Enterprise (TTE), responsible for operating the ferries and overseeing navigation on the lake. ii) the Fishers Cooperative representing lake fishers and promoting fisheries development	i) the Koga Irrigation Development Service Cooperative ii) farmers in communities adjacent to the scheme iii) the project office iv) the local authority (i.e. Wereda[3] administration)
Tertiary stakeholders	i) the Amhara Region Bureau of Water Resources (ARBWR) ii) the Amhara Region Environmental Protection, Land Use and Administration Authority (EPLUA) iii) the Amhara Region Parks Development and Protection Authority (PDPA) iv) the Amhara Region Bureau of Culture and Tourism (ARBCT) v) the Lake Tana Basin Research Centre vi) the Amhara Region Agricultural Research Institute (ARARI).	i) the Amhara Region Bureau of Water Resources (ARBWR) ii) the Amhara Region Environmental Protection, Land Use and Administration Authority (EPLUA) iii) the Amhara Region Bureau of Agriculture and Rural Development (ARARD) iv) the Amhara Region Cooperatives Promotion Agency

[3] Wereda is an administrative division of Ethiopia (managed by a local government), equivalent to a district. Weredas are composed of a number of Kebeles or neighborhood associations, which are the smallest unit of local government in Ethiopia.

1.3 Results

The results are presented below for each of the schemes separately. Common insights are drawn together in the discussion and conclusions.

1.3.1 Chara Chara weir

The study identified a range of issues and competing interests between the primary stakeholders, which in some cases are leading to conflicts (Table 1.3). There is no doubt that through the production of electricity, the Chara Chara Weir and Tis-Abay power stations have contributed significantly to the economy of Ethiopia. However, whilst some local people have gained as a result of the dam, others have lost.

Table 1.3. Summary of concerns raised by the Chara Chara weir stakeholders.

Stakeholders	**Issues Identified**								
	Reduced lake levels in the dry season	Wet season flooding	Increased dry season flows in Upper Abay	Reduced downstream flooding	Lack of warning of high flows downstream	Reduced flow over the Tis Issat Falls	Loss of vegetation around the lake	Declining lake fish population	Electricity produced
Primary									
EEPCo	N	N	N	N	N	-	N	N	+
Upstream Farmers	+	-	N	N	N	N	-	N	N
Downstream Farmers	N	N	+	+	-	-	N	N	-
Fishers	-	N	N	N	N	N	-	-	N
Negede	-	N	N	N	N	N	-	-	N
Hotel owners	-	-	N	N	N	-	N	-	+
Tour boat operators	-	N	N	N	N	N	N	N	N
Secondary									
Tana Transport Enterprise (TTE)	-	N	N	N	N	N	N	N	N
Fishers Cooperative	-	N	N	N	N	N	-	-	N
Tertiary									
Amhara Culture and Tourism Bureau (ARBCT)	-	-	N	N	N	N	N	N	+
Amhara Region Bureau of Water Resources (ARBWR)	N	-	N	N	N	N	N	N	+
Amhara Environmental Protection, land use Authority (EPLUA)	-	N	N	N	N	-	-	-	N
Amhara Parks Development and Protection Authority (PDPA)	-	N	N	N	N	N	-	-	N
Lake Tana Basin Research Centre (LTBRC)	-	N	N	N	N	-	-	-	N
Amhara Region Agriculture Research Institute (ARARI)	-	N	N	N	N	-	-	-	N

+ = viewed positively by the stakeholder; - = viewed negatively by the stakeholder;
N = not of concern to the stakeholder.

EEPCo noted the importance of the Tis Abay power plants to electricity generation in Ethiopia and perceive the power production as both a regional and national benefit. The company spokesman highlighted the Universal Electrification Access Programme which aims to increase access to electricity from 15% to 50% of the population over the five years, 2005 to 2010. Between 2005 and 2007 EEPCo claims to have increased access from 17% to 22% with an additional 758 towns and villages electrified in 2007. The company recognizes that the diversion to the power stations is adversely affecting the visual spectacle of the Tis Issat Falls[4]. However, the spokesman emphasized the fact that the shift to electricity lessens environmental degradation by reducing biomass fuel requirements. The company therefore believes that the power stations have overall resulted in a net environmental benefit. It was acknowledged that the cost of electrical appliances, in particular stoves and cookers, limits uptake by poor rural households.

Farmers living both upstream and downstream of the dam have broadly benefited from it. In upstream locations, increased drawdown of the lake has resulted in increased exposure of the lake bed and encouraged the practice of dry season recession agriculture. In 2003, the lake was drawn down to its lowest recorded level, farmers extended crop production onto about 562 ha of the lake bed, utilizing the moist nutrient rich silt deposits for both horticultural and cereal crops (EPLAUA, 2004). Downstream of the dam, farmers have benefited from reduced wet season flooding and, because of the guaranteed flows and consequent access to water in the dry season, have expanded small-scale irrigation schemes. Women, who collect water from the river for drinking and household use, have benefitted as a consequence of easier access in the dry season. One farmer downstream of the dam stated:

> *The weir has not caused us harm in anyway. In fact we are getting a greater supply of water in the dry season because of it.*

Other people have been adversely affected by the dam. Many of those living in the small community of Tis Abay, adjacent to the power stations and very close to the Tis Issat water fall complained that they have been negatively impacted. Surprisingly, the number of tourists visiting the Falls has increased in recent years (Shiferaw, 2007). This is partly the result of greater numbers of tourists generally in Ethiopia and partly because the Falls are still promoted as a major tourist attraction. Many of the tourists who visit Bahir Dar are unaware that flows over the Falls have decreased. However, according to local people, many visitors are now unhappy with the visual spectacle[5] and, because they are annoyed, refuse to buy locally made handicrafts. In the past the selling of these products contributed significantly to the income of many local people. Although a few people have gained employment at the power stations many have not. Hence, the loss of income from tourists has had a negative impact on the livelihoods of many local people which has not been compensated through alternative opportunities. The local community also complains that they have no access to electricity, despite the fact that the power stations are located very close to their village. Furthermore, development opportunities (e.g. a school and health center) promised when Tis Abay-II was built, have not been forthcoming. One local elder stated:

> *We have not benefited in any way from the power plant. This is despite constant appeals to the concerned regional authorities, filing petitions a number of times and pursuing the case over a long period. Four hundred households were promised electric power supply by EEPCo and required to pay registration fees for that purpose. However, it has not so far materialized and the area still remains without access to electricity.*

A significant number of people are dependent on fishing from Lake Tana. The development of the commercial fishery, using motorized boats, was initiated by an EU-sponsored Lake Fisheries Development Program in 1986. The establishment of the Fishers' Cooperative in December 1994 has added impetus to the development of the sector. Currently membership is 150 fishers of whom 134 are men and 16 women. Fishers complain that since the dam was constructed dry season drawdown of the lake

[4] The Falls, which are located about 300 m downstream of the abstraction point for the power stations, are an important part of the natural heritage of Ethiopia and a major tourist attraction

[5] This perception was validated by hotel managers who confirmed that tourists complained to them that the Falls are no longer as described in tourist books, brochures and publicity material.

has increased and resulted in the desiccation of reed beds and consequent loss of fish breeding habitat. This has been exacerbated by farmers clearing reeds to create fields. Extreme drawdown of the lake in 2003 made navigation difficult and resulted in the sinking of some boats when they hit submerged rocks. One fisher stated:

> *The shrinking of the lake dried out plant species vital for the reproduction of fish stocks, resulting in large loss of many fish varieties. That was not the only dire consequence. The further the lake retreated, the larger the area of lakeshore that turned into dry ground where fishers could no longer cast their nets. The fish have also moved further in toward the deeper parts of the lake which makes catching them more difficult.*

The Negede people have been particularly hard hit. They rely on papyrus reeds for much of their livelihood; using it to construct canoes for lake traders and other people who move around the lake by boat. They also use the reeds to make household utensils (such as baskets and mats) which they sell in local markets, both for utilitarian purposes and as tourist souvenirs. In addition they cut and sell papyrus trunks to urban people for fence making. Since the construction of the dam they complain that many of the papyrus beds have dried out and large areas have died. As with the fishers, they also complain that farmers have burnt and cleared reeds to cultivate crops. A Negede spokesperson stated:

> *We are extremely worried in relation to the Chara Chara Weir. If Lake Tana continues to shrink as the weir drains its water the likely scenario is that our livelihood will be destroyed, and together with it our future. Conflict with farming groups who cultivate the wetlands is unavoidable….*

Many people living in the vicinity of the lake use boat transport on an almost daily basis to attend school, visit health facilities and travel to and from markets. For example, many of the 10,000 inhabitants of Dek Island (the largest lake island) are dependent on growing of mangoes and are dependent on boats to get these to market. Tourists also use boats to travel to many of the islands to visit the monasteries. The head of the Tana Transport Enterprise (TTE) stated that navigation on the lake is seriously compromised when water-levels drop below 1,785 masl, which in one meter above the absolute minimum operating water level. When this happened in 2003, the cost arising because of service interruption and damage to boats is estimated to have been about 4 million Ethiopian birr (i.e., approximately US$ 400,000) (Alemayehu, 2008).

The government departments had differing views on the dam and its operation. The ARBWR took the view that the socio-economic benefits arising from the electricity produced significantly outweighed any costs. In contrast, staff at EPLAUA expressed concerns over the environmental impacts of the dam and its operation and the associated impacts on the Negede, fishers and communities dependent on tourism. Staff at the PDPA argued that the historic and cultural value of the lake, as well as the river corridor to the Tis Issat Falls, meant that the region should be designated as a protected area with much greater recognition of its heritage value in current management and future development planning.

A common view, expressed by many stakeholders and implicitly recognized by EEPCo and government departments, was that the decision-making processes in relation to both the planning and operation of the dam were not ideal. Both the TTE and the Fishers' Cooperative complained that the interests of the stakeholders they represent were totally ignored in the planning of the dam. This has been exacerbated by the lack of transparency and participation in decision making related to the way the dam is now operated. Both organizations feel that EEPCo's sole consideration is electricity generation and other stakeholder needs are simply ignored. The director of the LBTRC complained that they experience difficulties in obtaining data and information with which to make informed assessments of the benefits and costs of the dam and its operation.

1.3.2 Koga dam and irrigation scheme

As with the Chara Chara weir this study identified a range of issues and competing interests between the primary stakeholders, which in some cases are leading to conflicts. In this case, many of the identified issues related to the processes and decision-making pertaining to the payment of compensation for assets lost as a result of construction of the dam and inundation of the reservoir area (Table 1.4).

The reservoir will inundate an area of 18.6 km^2 of which 360 ha is cultivated, 5 ha is homesteads and the remainder is communal grazing for approximately 42,000 cattle. Approximately 602 households will be displaced by the project: 373 from the area of the reservoir and the remainder from the site of the dam and as a result of the construction of infrastructure (e.g. roads, night reservoirs and canals) in the irrigation command area. Another 4,473 households will lose assets as a consequence of the scheme.

Arrangements for resettlement and compensation were developed to comply with both the Constitution and civic code of Ethiopia as well as the African Development Bank's Operational Directive on Involuntary Resettlement (AfDB, 2003). A resettlement committee that comprised representatives of the local communities, government and the project management unit was established. All farmers who lost land as a consequence of the scheme were to be compensated with plots in the irrigation scheme. The majority of displaced households were to be resettled in "host" villages located close to the irrigation scheme. A small number of households have been moved to the outskirts of the nearby town of Merawi. Cash compensation was paid for loss of assets including buildings, infrastructure, crops and trees. Those farmers who, because of the timing of construction, had to be moved in the early phases of the project development were given monetary compensation for lost harvests for up to 3 years. It was anticipated that they would be cultivating in the irrigation scheme after these 3 years. Improved social services, including a clinic, school and flour mill as well as better water supply were promised.

The review found that there were many problems with the implementation of the compensation and benefit sharing scheme. Many people felt that there was inadequate communication and the way that compensation was determined was unclear and in many cases haphazard. One farmer claimed that he had lost significantly as a consequence of the scheme:

> *In the name* [of the scheme] *three hectares of land were seized from me. I was then given land meant to substitute for what I had lost. After having cultivated this for a year, someone claiming to be an heir of the deceased owner brought a lawsuit against me and grabbed the land from me by verdict of a local tribunal. On top of that, I was forced to repay the man the value of one-year of produce estimated at Birr 1,500 [US$ 150]. Then, I filed a demand with the project to pay me compensation for the land and the value of the crop that I lost. The reply I received was that I had to wait until the project was complete and irrigation land was allocated to me. I am now in dire straits… I have nothing to get me through.*

Table 1.4. Summary of issues identified by the Koga dam stakeholders.

Stakeholders	Issues Identified								
	Land redistribution process	Valuation of assets and amount of compensation	Timing of compensation	Health and education facilities	Attitude of host communities	Delay in completion of infrastructure	Local capacity to manage the irrigation scheme	Implementation of upstream soil conservation measures	Planning before project commenced
Primary									
Displaced farmers resettled in urban communities	+	+	-	+	+	-	N	N	N
Displaced farmers resettled in rural areas	-	-	-	-	-	-	N	N	-
Farmers waiting to be displaced	-	-	N	N	-	N	N	N	-
Host Communities	-	N	N	-	N	N	N	N	-
Secondary									
Farmers in adjacent villages not directly affected by the project	N	N	N	N	N	-	N	N	N
Project office	N	+	N	-	-	-	-	-	-
Koga Irrigation Development Service Cooperative	-	-	N	N	-	-	-	-	N
Mecha Wereda Administration	-	-	N	N	N	-	+	N	N
Tertiary									
Amhara Region Bureau of Water Resources	N	N	N	N	-	N	-	-	-
Amhara Region of Agriculture and Rural Development	N	N	N	-	N	N	N	-	-
Amhara Environmental Protection, land use Authority	N	-	-v	N	N	N	N	-	N
Amhara Region Cooperatives Promotion Agency	-	-	N	N	-	-	N	-	N

+ve = viewed positively by the stakeholder; -ve = viewed negatively by the stakeholder; NC = not of concern to the stakeholder.

Many farmers claimed that assets had not been properly valued. For example, one woman stated:

> *[When] my husband was out… they came to cut down the line of eucalyptus trees that we had planted around our house. I argued that they should not be cut down before they were counted and their value assessed. The operation of removing the trees went ahead before the argument was resolved. Hence, no count was made.…*[and] *they paid only Birr 2,500* [US$ 250]*, which did not represent the actual loss. The compensation would have been greater if the trees had been counted.*

Because of delays in the project start-up the 3 years were nearly over, but no land in the scheme had been allocated and yet no additional compensation was forthcoming for those farmers who had lost land at the start. Furthermore, because, over the 3 years, food prices had increased substantially these farmers felt that they had not received adequate compensation for their lost harvests. The following quote was typical of many farmers:

> *…we were paid the estimated value of the crop produce that we would have been able to harvest over a period of three years, if the project had not commenced and interfered with farming activities. Nevertheless, the value assessment was made on the basis of crop prices at the market three years ago. Three years on, market prices have soared, for example, from Birr 200 to Birr 500* [US$20 to US$50] *for a quintal of teff. For this reason the assessment does not represent the value of the produce that we have foregone.*

Those households that had been relocated on the outskirts of the nearby Merawi town, were reasonably happy and felt that they had benefited in several ways. Firstly they now inhabit an area where malaria does not pose a threat. This contrasts with their home village which was "malaria-infested". Secondly, they have much better access to health and education facilities than they had in the past. Thirdly, they own the land on which their new homes have been built and they consider this to be a valuable asset. However, more broadly the promised improved social services for those not relocated to Merawi (i.e. improved water supply, a clinic, school and flour mill) had, at the time the survey was conducted, not materialized.

Farmers in villages adjacent to, but not directly affected by, the project, generally had more positive opinions about it. They foresaw various direct and indirect benefits arising from the scheme. Firstly, they hoped that the project will provide them an opportunity to engage in irrigation farming on a sharecropping basis. They hoped that some irrigation farmers will rent them small plots of land. Secondly, they anticipate that with the advent of irrigation agriculture, specialization will be introduced and greater focus will be given to the production of fruits and vegetables. In their opinion, the emphasis on horticultural crops with a commercial value will strengthen market interaction between the irrigation farmers and themselves. Thus, they believe they will be in a position to obtain fruits and vegetables, while they market cereal crops, livestock and dairy products.

By far the biggest concerns about the project were raised in relation to the social upheaval that was anticipated by many who were to be relocated. The study found that there was considerable mistrust and animosity between the host communities and those who would be relocated. A commonly expressed view, within the host communities, was that the displaced people should not be moved to "their" villages and should not be allocated land within the irrigation scheme. Many felt that the people being displaced had received adequate compensation for lost assets and they did not deserve land in the scheme, particularly as they themselves would have smaller plots of land in the irrigation scheme than they currently farmed and would not receive compensation for the difference. The view was most succinctly stated in one interview:

> *…we do not feel comfortable sharing land and co-existing with people we have never known before. It is hard for us to trust and get along with outsiders…*

Physical threats had been made. One farmer, waiting to relocated, reported a conversation he had had with a resident of the village in which he was to be relocated, in which he was told:

> *I wish the dam waters or the Koga River swept you away, so that you perished before you came over to share our land. If you ever dare to set foot on our land, after collecting your compensation, you will lose your neck from the upper part of your body, and your thighs, from the lower end.*

Not surprisingly, people who were supposed to move to the host villages expressed grave concern about the reception they would receive and if they would be able to settle.

Although most of the regional government departments acknowledged that in the short-term the scheme was causing significant social disruption, they believed that in the medium to long-term the scheme would bring significant benefits to the region, creating employment and business opportunities linked to marketing of high value crops and food processing etc. They also believed that there would be job opportunities for skilled personnel associated with the operation of both the dam and the irrigation scheme. Consequently, overall they expressed confidence that the scheme would make a positive contribution to livelihoods in the region.

The main concerns of the government officials interviewed related to:

- The recognized hostility of host communities to those displaced households being moved into their villages and the difficulty of securing host community cooperation.
- The practicality of the envisaged full cost recovery for the scheme.
- The limited experience of local communities to manage irrigation schemes and hence what the best institutional arrangements would be for ensuring the long-term sustainability of the scheme.
- The lack of progress with the watershed management component of the scheme and hence the risk of sedimentation of the reservoir.

The project office acknowledged that the social and environmental aspects of the scheme had not been given the same attention as the engineering and physical aspects. As a result, the office felt that these issues had only been dealt with relatively late in the project and planning could have been better. Hence, although not strictly in the mandate of the project office, it was constantly having to negotiate with villagers over compensation issues. This was perceived to be a major drain on the time and resources of the office and there was a general feeling that better awareness raising and community mobilization earlier in the project would have avoided many of the problems.

Nevertheless, the project office expressed confidence that communities would benefit not only in the long-term, but had already benefited. They believed that the communities had not lost out to the extent that some claimed. Their perception was that compensation paid had been fair, based on adequate inventory, valuation of assets and estimation of crop losses. In addition, at least 300 members of the farming communities had gained employment in the project as daily labourers and guards. Overall, the general perception in the project office was that there would be “no losers” as a consequence of the scheme.

1.4 Discussion

Both analyses highlighted the divergence in values, needs and interests of individuals and different stakeholder groups. They showed that the implementation of large dam projects have a significant effect on the social landscape of the areas in which they are located. It is clear that changes caused by the construction of dams, both in the past and currently, have affected the customary and *de facto* entitlements to natural resources, environmental quality and social-cultural integrity experienced by communities living in their vicinity.

For the Chara Chara weir it is clear, that although the primary beneficiary has been the economy of Ethiopia, some local people have gained through its construction. However, little or no consideration has been given to those who have been adversely affected by the dam and the way it is operated. For the Koga dam and irrigation scheme, it seems that there have been irregularities in the handling of compensation. This in conjunction with the delay in construction has resulted in the project being viewed with distrust by many local people, including those communities who are the intended beneficiaries.

It is apparent that decisions pertaining to both the Chara Char weir and the Koga dam have largely been made with little or no public consultation and with insufficient explanation of the intended project outcomes. In both cases the lack of consultation and public involvement in decision-making processes has fuelled controversies and resulted in wide-spread rumors and speculation about the function of the schemes, their impacts and whether or not they bring (or will bring) tangible benefits.

1.5 Conclusion

The concerns relating to large dams are complex, encompassing many interlinked social, economic and ecological dimensions. Clearly the social complexity of such schemes requires that social components should be given as much, or even greater, consideration than technical aspects in project planning. It is clear that to minimize unwarranted social stress, requires that all stakeholders understand the scheme and participate in decision-making from an early stage. For schemes such as these, mechanisms that lead to increased cooperation and consensus building between different stakeholders are necessary.

Further details of these stakeholder analyses are presented in Gebre *et al*, 2007a,b and, for the Chara Chara weir, in McCartney et al. (in press).

2 Objective 2: to enhance stakeholder participation in regulation studies of the Equatorial Nile

2.1 Background

The operation of dams and large reservoir systems is often complicated by a multiplicity of conflicting project uses and purposes that ultimately affect different groups of people or interests. Resolving the dam operation problem is compounded by system managers who do not easily perceive the trade-offs and often resort to assigning priority to objectives that realize the greatest monetary benefit. For example, between 2000 and 2005, in the Upper Nile Equatorial Lakes Basin (Figure 2.1), hydropower plants at the outlet of Lake Victoria increased power generation, by releasing greater volumes of water through their turbines than is consistent with the Agreed Curve[6] (Figure 2.2). Over the same period Lake Victoria levels dropped close to unprecedented lows. The role of hydropower production in this decline is not clear and has been much debated. Nevertheless it is clear that low lake levels had an adverse impact on landing sites, navigation facilities and shoreline industries and settlements, leading to a range of mostly negative socio-economic and ecosystem impacts. Several recent studies have utilized Decision Support Systems (DSSs) to assess the impact of different regulation rules on hydropower production (e.g. Mott MacDonald, 1998; Georgakakos, 2004; Wardlaw *et al*., 2005). However, to date no progress has been made in implementing any of the identified plans. It is probable that failure to consider environmental impacts and the lack of a framework to support consideration and adoption of new regulation strategies has impeded progress. In this section, the findings of a consultative exercise designed to clarify different stakeholder opinions, and agree upon broad management objectives are presented.

[6] An internationally agreed release regime, based on the relationship between outflow and Lake Victoria level that existed prior to construction of the Owen Falls Dam.

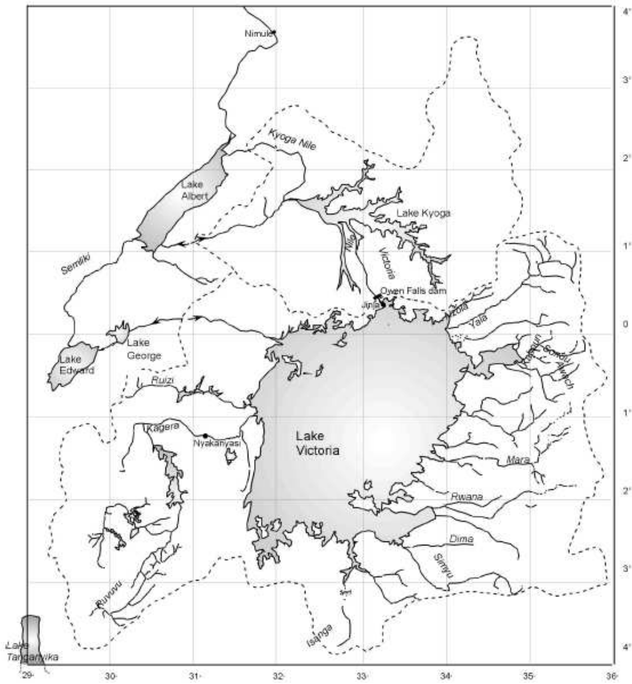


Figure 2.1. Equatorial Lakes Basin (Sutcliffe and Parks, 1999)

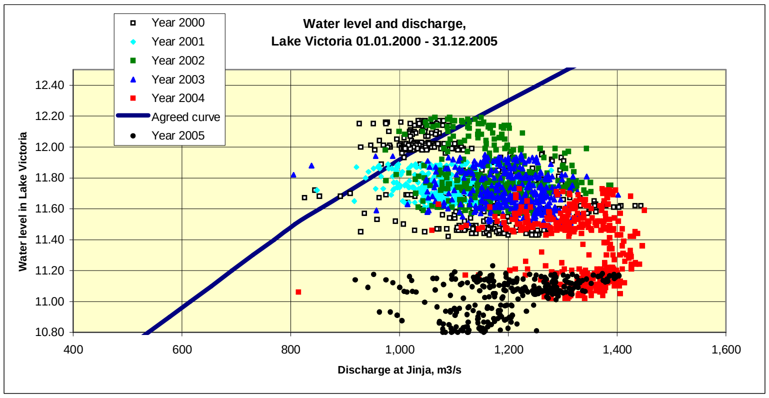


Figure 2.2. Monthly releases from the Lake Victoria Dams (2000-2005). Most points lie to the right of the Agreed Curve, indicating excessive releases for hydropower production.

2.2 Method

A stakeholder meeting was organized and held in Entebbe in Uganda in July 2007. The meeting attracted participation from representatives of a wide range of stakeholders from the three riparian countries of Lake Victoria (Table 2.1). The aim of the meeting was to achieve a common understanding of stakeholders' interests and desired goals. A number of presentations were made to facilitate discussion around different stakeholder positions. Key amongst these was a presentation made by ESKOM (the operator of the dams) which illustrated the challenges facing the company in resolving water sharing issues within a framework of cascading hydropower plants along the Victoria Nile. Presentations were also made on the legal aspects of public participation in the planning and management of large dams and stakeholder participation methodologies, processes and techniques in DSS frameworks. Extracts of relevant literature were presented to the participants to facilitate their examination of problems similar to the one under consideration (e.g. Soncini-Sessa *et al*., 2002; Castelleti *et al*., 2004; Marttunen and Suomalainen, 2006).

Table 2.1. Stakeholders that participated in the priority setting workshop (July 2007)

• Uganda Water Policy Committee • Directorate of Water Resources Management in Uganda • Uganda Dams Dialogue • Nile Basin Discourse Forum • Ministry of Energy and Minerals Development in Uganda • Fisheries Research Institute (FIRRI) • ESKOM Uganda, the dam operator • Confidence Building and Stakeholder Involvement Project of the Nile Basin Initiative	• National Association of Professional Environmentalists (NAPE) • Lake Kyoga Integrated Management Organisation (LAKIMO) • University of Dar Es Salaam, Tanzania • Moi University, Kenya • Water Resources Management Authority in Kenya • Lake Victoria Research Initiative (VICRES) • Secretariat of the East African Community (EAC)

During break out sessions, stakeholders with similar concerns were grouped into "sectors" (e.g. "Fisheries & Environment") and asked to articulate their preferences and identify criteria to be used in the evaluation of a proposed regulation policy. Eliciting preferences was not straightforward as many of the participants were not aware of, or sure about, their preferences amongst several management objectives. Consequently they were not able to state them exactly. Hence, they were asked to initially define a wide range of objectives from their perspective and rank them in order of importance based on their own interests. These were then presented to a plenary session for discussion.

An objectives hierarchy or decision hierarchy method commonly referred to as "Value Trees" (Martunen and Hämäläinen, 1995; Rogers and Bestbier, 1997) was utilized to support the ranking process. The method begins with formulation of a broad management vision and specific management goals that give better definition to the vision, and is ultimately underpinned by a set of specific, quantified objectives which provide managers with management targets. Quantified objectives can include proposed levels of hydropower generation, desired range of lake levels, flood control, damage or targets of ecosystem integrity. In the workshop priority issues were identified under four broad themes: economic, social, ecological and institutional. Specific management objectives were finally validated in the plenary session by a method of approval vote ranking.

2.3 Results

Each of the stakeholders articulated their own priorities. Representatives from NAPE sought to define management objectives that take into account issues related to cultural, spiritual and ethical values. However, they were urged to be prepared to make some concessions due to the difficulty of incorporating such non-tangible considerations within a DSS framework. Representatives from ESKOM argued that an underlying seasonality in annual Lake Victoria levels implies that alternatives to the Agreed Curve method of operating the dams should take into account the fact that more water is available between April and September each year. ESKOM also indicated that additional challenges in dam operation would arise once downstream power plants along the Victoria Nile were completed and expressed concern that, over the long term, large-scale withdrawal of water from Lake Victoria by upstream riparian countries would impact negatively on hydropower production. It was proposed both factors must be taken into account in the design of future operating policies. FIRRI focused on the need to maintain both upstream water levels as well as downstream flows to maintain important fisheries production in wetland areas. LAKIMO emphasized the importance of the Lake Kyoga for the maintenance of many rural livelihoods and the need for timely inflows from the Victoria Nile to safeguard these livelihoods. Representatives from both Kenya and Tanzania highlighted the importance of Lake Victoria for many of their citizens and the problems of excessive drawdown on the water supply to several large towns. Figure 2.3, illustrates a value tree developed by one of the working groups.

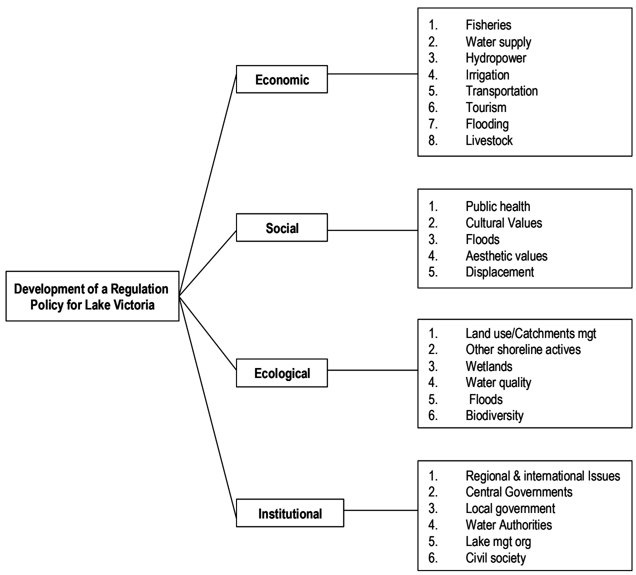


Figure 2.3. Value tree developed to highlight key issues to be considered in the regulation of outflows from Lake Victoria

The agreed priorities for future Equatorial Lake Regulation plans that emerged from the meeting were:

- Maximize hydropower production along the Victoria and Kyoga Nile.
- Sustain biodiversity, fisheries and wetland resources.
- Satisfy foreseeable water resources requirements of the riparian countries.
- Minimize disruptions to shoreline settlements & infrastructure from both excessively high and low water levels.
- Satisfy existing International Agreements between riparian countries & legal obligations of power producing companies e.g. power purchasing agreements as much as possible.
- Preserve icons of culture.

2.4 Discussion

The workshop underscored the diversity of concerns and the wide range of stakeholders with interests in how the waters of the Equatorial Lakes Basin are regulated. It proved to be a useful forum for discussion of concerns and, facilitated by the use of Value Trees, enabled the development of a broad consensus on the range of priority issues related to the operation of dams. Ideally dam operating regimes need to be tailored to ensure that, as far as possible, all these objectives are met. However, it is clear that pragmatically some trade-offs will be required (e.g. between maximizing hydropower production and minimizing disruptions to shoreline infrastructure and ecosystem requirements). The strength of modern DSSs is being able to predict the implications of different operating regimes for a range of objectives. The workshop did not succeed in developing quantitative objectives. Nevertheless, the consensus on priority issues provides a useful basis for determining the focus for a DSS. The development of a DSS to evaluate these priority issues is currently underway (Zaake, forthcoming).

2.5 Conclusion

The work highlighted the fact that decision-making related to dams is not simply an intellectual exercise related to optimizing benefits, but is in fact highly emotive. In such complex situations, where the potential for conflict is high, the decision-making process is as important as the final outcome. Although the impacts of the workshop itself are difficult to evaluate it certainly promoted better mutual understanding of different stakeholder concerns. It also contributed to transparency in decision-making and fulfilled the objective of providing a firm foundation for further development of a DSS for dam operation in the basin.

Further details of stakeholder involvement and application of DSS for large dam planning and operation in the Equatorial Nile are presented in Zaake (2007a,b) and will be further elaborated in Zaake (forthcoming).

3 Objective 3: To evaluate the effectiveness of EIA follow-up after large dam construction

3.1 Background

Environmental Impact Assessments (EIAs) are currently the most widely accepted process for identifying, predicting and mitigating the ecological and social impacts of development proposals and activities. They also help to assist decision-making and to attain sustainable development. The effectiveness of any EIA depends on several factors, among which the quality of EIA guidelines, EIA reports and implementation and follow-up of EIA recommendations are of particular importance (Arebo, 2005). Without some form of systematic follow-up to decision making, EIA can simply become a paper chase to secure a development permit, rather than a meaningful exercise in environmental management to bring about real environmental benefits. This is a recognized problem not only in the developing world, but also in many developed countries: implementation of EIA recommendations is frequently not done well (Noble and Storey, 2004). Successful implementation of EIA recommendations requires that both policies and institutions are strengthened to facilitate adequate follow-up.

The aim of this component of the project was to determine the critical factors affecting the successful implementation of EIA mitigation measures, developed to minimize environmental and social impacts of the Koga irrigation and watershed management project in the Lake Tana basin (see objective 1 for details of the scheme). The research questions addressed were:

- To what extent have EIA-recommended mitigation measures been implemented by the project proponent?
- How do regulatory bodies ensure implementation of EIA-recommended mitigation measures?
- How and to what extent did the public participate in the EIA process?
- What are the likely downstream impacts of the project and to what extent where they considered?

3.2 Methods

The method comprised both a literature review and fieldwork. The literature review centered on issues of sustainability as well as EIA experiences in Ethiopia and other countries. In addition, project specific reports (i.e., the Environmental Management Plan (EMP), accomplishment reports, monitoring reports and permit conditions) were reviewed. In the fieldwork, both semi-structured and structured questionnaires were used. This enabled the perceptions and opinions of specialists (i.e., from the project and the Ethiopian Environmental Protection Agency (EPA)), the communities (i.e., located both upstream and downstream of the dam) and management bodies (i.e., from the project, EPA and other institutions) to be gathered. The extent of public participation in the project was assessed using "the Aarhus practice evaluation criteria for public participation", adopted from the European convention on public participation (Hartley and Wood, 2004). Finally, observations were made, by visiting the site, to independently assess the accomplishments of the EIA-recommendations. Analyses conducted included comparison of the perceptions of different stakeholders on the accomplishment of the project with the EMP and the accomplishment reports.

3.3 Results

Most of the documents (Acres and Shawel, 1995; WAPCO and WWDSE, 2005; KIWMaP, 2006; EPLAUA, 2006; MacDonald, 2004a & 2004b; AfDB, 2000; AfDB, 2001; and McDonald, 2006a & 2006b) fulfill requirements and provide satisfactory information on the probable impacts of the scheme as well as mitigation measures to minimize environmental problems. Predicted impacts considered in the EMP include impacts on: water resources; water quality; air environment; noise environment; land environment; ecological aspects; impacts due to command area development or induced development; demographic impacts and socio-economic aspects. The document describing the Environmental Flow Assessment (EFA) of the project indicates that the Q95 method was used (WAPCO and WWDSE, 2005). This method does not address the variable nature of the hydrological regime. There is no mention of likely impacts of the dam on downstream flooding, fisheries and riparian vegetation. Review of the EMP indicates some limitations in the planning process, including:

- no process of public consultation
- no evaluation of different project scenarios and possible alternatives,
- no monitoring plan for erosion and siltation,

Review of the project progress reports indicates that of the 20 major plans identified in the EMP for implementation only two activities (i.e., planting forest seedlings and livestock development) have progressed satisfactorily. Three activities (i.e. watershed management measures, public health and resettlement/compensation payments) were progressing unsatisfactorily. The remaining 15 activities were either moribund or not reported.

3.3.1 The community (Farmers)

Interviews conducted with farmers focused on public participation and implementation of mitigation measures. Farmers were asked to comment on the likely impacts of the scheme, what they knew about the EIA and more generally how decisions relating to the scheme were communicated to them. Farmers were asked if project material was presented in a way that was understandable to them. The study found that many farmers recognize the possible environmental impacts that could affect their livelihoods. Downstream communities expressed concerns about adverse impacts on: drinking water, fisheries, traditional irrigation, forestry products and firewood etc. From the 42 interviews conducted it was also found that: 19% of the interviewees agreed that *communication* criteria for the project were completely fulfilled, 14% nearly fulfilled and

26% partially fulfilled. The remaining 41% said that the project did not provide project materials in a clear format, implying that communication criterion were not fulfilled. Thus nearly half of the interviewed people living in the catchment do not have a clear understanding of the project documents or the project itself, based on the materials provided by the project team. Moreover, neither downstream nor upstream farmers felt that they had participated in decision-making related to the project. These findings confirm those of the stakeholder analysis (see objective 1) which indicated that decisions pertaining to the construction of the dam have been made with little public consultation and with insufficient explanation of intended project objectives.

3.3.2 Specialists

The interviews conducted with specialists focused on implementation of EIA recommendations and the EMP. The results obtained from the interviews indicated that 70% of the specialists thought that the environmental mitigation measures recommended in the EIA were not being adequately implemented. In addition, 90% of the specialists thought that the EMP was constrained by weaknesses in institutional arrangements, time schedules, finance, limited integration of the EMP within the overall project schedule and limited capacity of project staff.

3.3.3 Management Bodies

The interviews with staff from the management bodies focused on the institutional arrangements and regulations to ensure that EIA recommended activities are undertaken. It was found that the Koga project has no official permit, as officially required by national environmental legislation. Instead, the African Development Bank (i.e., the donor funding the scheme) required that an EIA was undertaken and then approved the EIA documents. The African Development Bank also prepared its own EIA summary (AfDB, 2000). There are several national institutions involved with the scheme:

- the Amhara regional water resources bureau is responsible for hosting the project management unit which coordinates the construction and implementation of the project;
- the Amhara regional agriculture bureau is responsible for implementing the watershed management component;
- the Environmental Protection, Land Administration and Use Authority (EPLAUA) is responsible for overseeing environmental aspects of the project and is also responsible for land redistribution and compensation.

Staff interviewed in these institutions, either knew nothing or stated that they had "no opinion" about the lack of an official permit. There were no environmental specialists in either the scheme management team or the various consultants employed by them. Consequently, the project has not undertaken any formal monitoring of environmental impacts. Furthermore, the EPLAUA has only undertaken surveillance/monitoring once in the four years since the project commenced. There is no regular monitoring of any environmental impacts and recommendations for monitoring made in the EIA are not being adhered too. For various reasons, including lack of capacity and financial constraints, the institutions tasked with ensuring that the EIA recommendations are implemented are not fulfilling their responsibilities.

3.4 Discussion

The primary objective of EIA follow-up activities should be to ensure that project managers are able to realize intended project outcomes. As this study has shown the effectiveness of the follow-up in the Koga scheme is limited with weaknesses in several key areas (Figure 3.1). Constraints arise for technical reasons as well as limitations in human, financial and technical capacity. Key limitations are:

- lack of monitoring which means that managers are unable to make informed decisions;
- lack of relevant expertise in the project management team;
- a weak regulatory and institutional framework;
- lack of public participation and the absence of a strong civil society to ensure that EIA recommendations are implemented

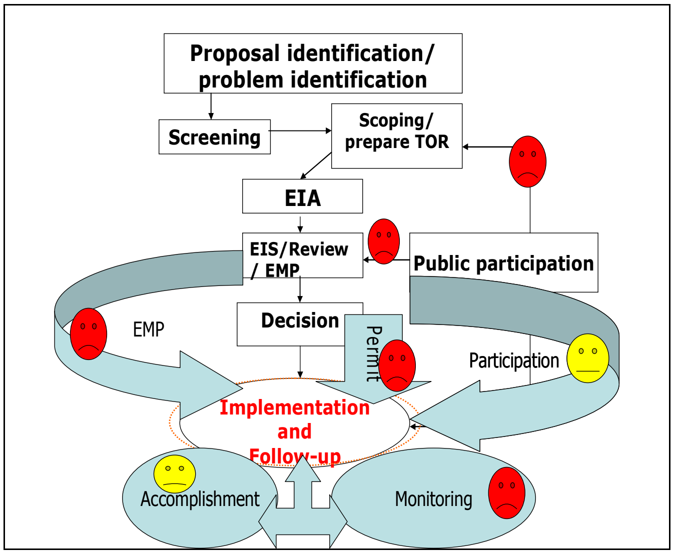


Figure 3.1. Schematic illustrating points of weakness in the EIA process undertaken for the Koga Irrigation and Watershed Management Project

As a result of these limitations, it is not possible to ascertain the long-term consequences of cumulative environmental impacts and it is possible that the sustainability of the scheme could be undermined.

It is recognized that all development projects have adverse biophysical consequences. Ideally these will be kept to a minimum through the proper implementation of recommendations from EIAs. Based on the study findings the following recommendations were made to improve EIA follow-up in development projects in Ethiopia:

- Enforcing certification mechanisms provides a critical first-step in the EIA follow-up process and is essential if project proponents are to take their environmental responsibilities seriously.
- Implementation of EIA follow-up measures would be greatly improved by clearly defining and dividing tasks and responsibilities between those organizations which are supposed to implement them.
- Mechanisms are required to strengthen public participation in project decision-making processes. This is essential to ensure cooperation and consensus building between different stakeholders.
- Project management teams need to take environmental concerns seriously. It should be mandatory that they include staff with relevant environmental expertise and the knowledge required to implement EIA recommendations and monitoring requirements.

- The finances required to implement EIA recommendations should be identified and ring-fenced at the commencement of projects. This should include funds required by the relevant regulatory bodies to monitor compliance.
- Appropriate incentives and legal mechanisms need to be developed to encourage compliance with EIA recommendations.

3.5 Conclusion

The Koga scheme is the first in Ethiopia to combine both irrigation and watershed management, within a project that will ultimately be managed by local farmers. Consequently, it is widely perceived to be a learning experience which can be used to inform future irrigation development in the country. To this end, the lessons learned in relation to EIA follow-up have been communicated to government representatives in various fora, including one workshop attended by the Minister of Water Resources. To maximize the benefits to be gained from future development projects (not only irrigation schemes) it is essential that the lessons learned are acted upon.

Further details of this component of the project are presented in Abebe (2007) and Abebe et al. (2008).

4 Objective 4: To determine the malaria implications of large dam construction and investigate the possibility of using dam operation as a tool for mitigation

4.1 Background

Past experience shows that inadequate consideration of both environmental and public health impacts can seriously undermine the envisioned benefits of investments in large dams. Key among the potential negative effects of large dams is intensified malaria transmission, resulting from changes in environmental conditions that increase vector (i.e. *Anopheles* mosquito) abundance (Keiser et al. 2005).

Studies demonstrating the efficacy of conventional malaria control strategies are abundant (Lengeler and Snow 1996). However, there are also many examples highlighting their limitations (e.g. Guyatt et al. 2007). Lack of financial resources for medical and chemical control measures is a major constraint on broader use in sub-Saharan Africa. Their efficacy is further reduced as a consequence of resistance of mosquitoes to insecticides and the malaria parasite to drugs. This calls for cost-effective and efficient malaria control measures such as environmental management through larval habitat modification.

Recent research has devoted increasing attention to environmental management, particularly water management, to reduce malaria incidence (Utzinger et al. 2001; Yohannes et al. 2005). Appropriate management of mosquito larval habitats can help suppress malaria transmission (Tennessee Valley Authority 1947). The main objectives of this component of the project were to investigate:

- the impact of impounded water on mosquitoes and malaria in an area of seasonal transmission;
- the possibility of using dam operation as a tool for malaria reduction.

4.2 The study area

In Ethiopia, malaria affects around 4 to 5 million people annually throughout the country, with morbidity and fatality rates of 13 to 35% and 15 to 17%, respectively (Ministry of Health, 2005). *Anopheles arabiensis* and *An*. *pharoensis* are the major malaria vectors in the country. This component of the project comprised both epidemiological and entomological surveys conducted in the vicinity of the Koka reservoir (storage 1,500 Mm^3) in Central Ethiopia, which is located in the Awash River Basin at 1,590 m above sea level, approximately 100 kilometer south-east of Addis Ababa (Figure 4.1). The dam, commissioned in 1960, was built primarily for hydropower generation. However, it is now also used for downstream irrigation and flood control.

Most households in the area depend on subsistence rain-fed agriculture and livestock-herding. Most people live in traditional mud huts, known as "tukuls". Malaria is seasonally demarcated, with peak transmission following the wet season, generally lasting from mid-September to mid-November. Malaria control authorities in the region seek to reduce malaria risk mainly by means of indoor residual spraying (IRS) with DDT and other pesticides in selected villages and by treatment of diagnosed cases with anti-malarial drugs.

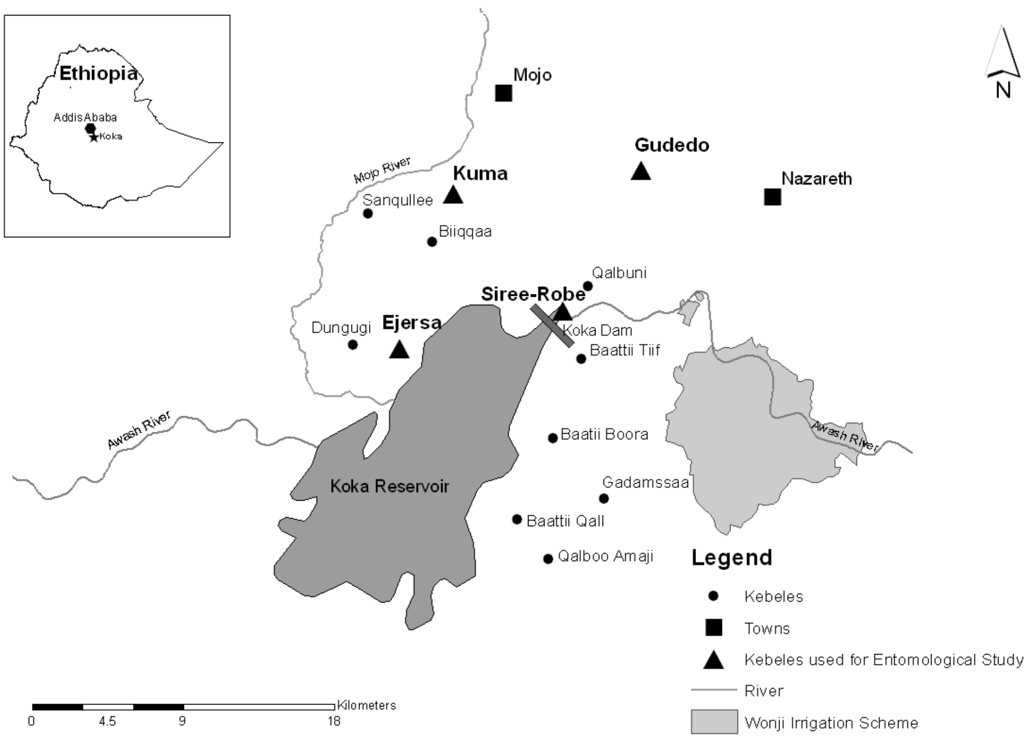


Figure 4.1. Map of the Koka reservoir. The dam is located at the northeast corner of the reservoir. The triangles represent each of the study villages used in the entomological survey. The circles represent additional villages for which data were obtained for the epidemiological studies.

4.3 Methods

Both epidemiological and entomological studies were conducted. The epidemiological survey utilized secondary data and combined long-term malaria case data with information on reservoir operation and climate. The entomological surveys collected primary data on both adult mosquitoes and larvae breeding habitats in selected villages located at different distances from the reservoir.

For the epidemiological study, records of laboratory-based malaria diagnoses were obtained for the period September 1994 to November 2007 from three malaria control centers located in towns close to the reservoir. Data were obtained for a total of 13 kebeles (i.e. villages) located within 9 km of the reservoir (Figure 4.1). The location of each patient's residence was recorded in terms of the person's village. The coordinates of the centre of each village were determined using a GPS and the distance between each village and the reservoir shore was calculated at the average capacity of the reservoir. Daily reservoir water-level data were collected from EEPCo for the period between January 1997 and December 2007. Time series of meteorological variables (i.e. rainfall, air-temperature and humidity) were collected from the National Meteorological Agency for stations operated in the vicinity of the reservoir, namely, Koka Dam, Mojo and Nazareth (Adama).

Population data from the Ethiopian Central Statistics Authority (CSA) were used to generate malaria case-rates (confirmed malaria diagnoses per 1000 persons) for each village. Changes in population between census dates were assumed to be linear, with a single population estimated for each year of record. A cohort analyses was undertaken to determine the impact of proximity to the reservoir on malaria case rates. For this, villages were divided into four groups, based primarily on the number and geographical spread of villages from which data had been obtained:

- those located within one kilometer of the reservoir
- those between one and two kilometers from the reservoir
- those between two and five kilometers from the reservoir
- those between five and nine kilometers from the reservoir

Multiple linear regression techniques were used to explore the association between number of malaria cases and potential explanatory variables. Stepwise linear regression in SPSS was used to identify significant explanatory variables (Draper and Smith 1998).

For the entomological study, four villages (i.e. Ejersa, Siree-Robe, Kuma and Gudedo) were selected based on their proximity to the reservoir. Ejersa and Siree-Robe are adjacent (0.4 to 0.8 km) to the reservoir, and the other two control villages (Kuma and Gudedo) are 6-10 km away from the reservoir shore. All the villages lie within altitude range 1500-1600 m. The entomological surveys comprised the collection of both larval and adult mosquitoes. Surveys were conducted fortnightly in the four villages between August 2006 and December 2007. During each larval survey, all available potential mosquito breeding habitat within one kilometer radius of each village was inspected for the presence of mosquito larvae using a standard dipper (350 ml). Potential mosquito breeding habitats in the study area included seepage at the base of the dam, reservoir shoreline puddles, manmade pools, agricultural field puddles and rain pools. Adult mosquitoes were sampled using CDC light traps (Model 512; J. W. Hock Co., Atlanta, USA). In each village, a total of six light traps (four light traps installed in randomly selected occupied houses and another two were deployed outdoors on trees) were operated from 1800 to 0630 hours throughout each sampling night. Mosquitoes caught in each light trap were counted and kept in separate paper cups. Larval and adult *Anopheles* species were identified based on morphological characteristics (Verron 1962a; 1962b).

Comparisons of monthly larval and adult mosquito densities between the reservoir and control villages were done using nonparametric Mann-Whitney *U*-test. Larval density was expressed as the mean number of anopheline larvae per 100 dips, and adult density was expressed as the mean number of mosquitoes collected per light trap-night. Bivariate and multivariate regression analyses were undertaken to identify the strength and nature of the relationship between water-level changes and malaria case-rates. All analyses were done using Microsoft Excel 2003 and SPSS version 13 (SPSS Inc, Chicago, IL, USA).

4.4 Results

4.4.1 Impact of the reservoir on malaria case rates

Clinically diagnosed malaria case-rates were correlated with proximity of residence to the Koka reservoir. No potential confounding factors were considered. Although there was considerable inter-annual variation, the mean annual malaria case-rates were greatest in the villages located closest to the reservoir and decreased as distance to the reservoir increased. A strong statistical relationship ($R^2 = 0.91$; $P < 0.001$) was confirmed between annual case rates and logarithmically transformed distance to the reservoir (Figure 4.2).

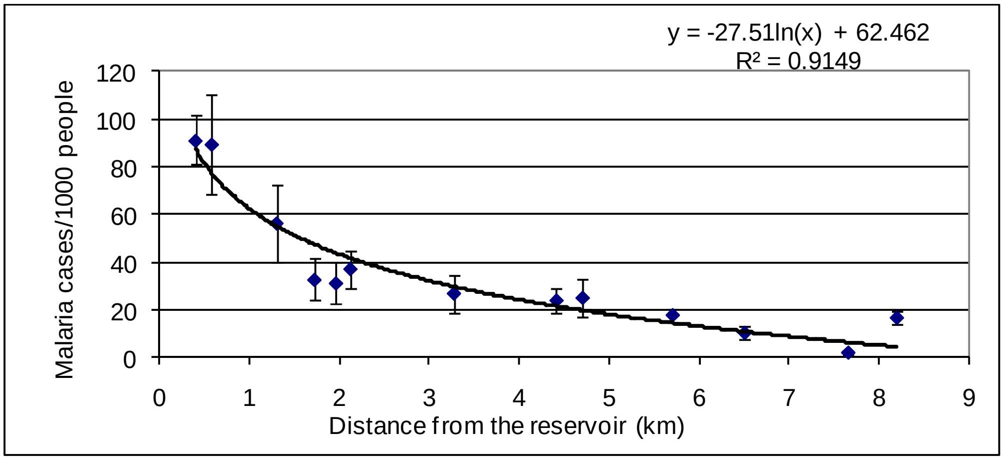


Figure 4.2. Relationship between average annual malaria cases rates in 13 villages and proximity to the Koka Reservoir between 1995 and 2007. The bars indicate the confidence interval of the observed means.

The cohort analyses indicated that, on average, the average annual malaria cases among people living within 1 kilometer of the reservoir was 2.9 times as great as for those living between 1 and 2 kilometers from the reservoir, 3.7 times as great as for those living 2 to 5 kilometers from the reservoir and 19.9 times as great as for those living 5 to 9 kilometers from the reservoir (Table 4.1). The differences between groups were statistically significant ($P < 0.001$) (Table 4.1). These results confirm that malaria prevalence is greater among people living close to the Koka reservoir than among people living farther away.

Table 4.1. Results of cohort analyses – annual malaria case rates.

Cohort	Distance from reservoir (km)	Annual cases per 1000 people	95% CI	Rate ratio[a]	95% CI[b]	p-value[c]
1	0 – 1	90.4	77.0-103.8	-	-	-
2	1 – 2	37.0	28.3-45.6	2.9	2.2-3.6	<0.001
3	2 – 5	28.0	21.5-34.6	3.7	2.9-4.6	<0.001
4	5 - 9	5.3	4.3-6.4	19.9	14.2-25.5	<0.001

[a] rate ratio is the ratio of case rates in each cohort to cohort 1
[b]CI = confidence interval [c]p = significance test at 0.05

The cohort data were examined to determine the impact of proximity to the reservoir on seasonal malaria case rates. The results showed a statistically significant seasonal variation in malaria case rates in all cohorts, with the peak recorded between October and December. They also indicate that proximity to the reservoir increases malaria risk at all times of year (Figure 4.3). Overall, within 1 km, the reservoir adds approximately 40 cases per thousand people in the rainy season and approximately 15 cases per thousand people in the dry season. These results are statistically significant. Therefore the impact of the reservoir is both to increase the malaria risk during the rainy season, when transmission is most intense, and also to effectively extend the malaria transmission into the dry season.

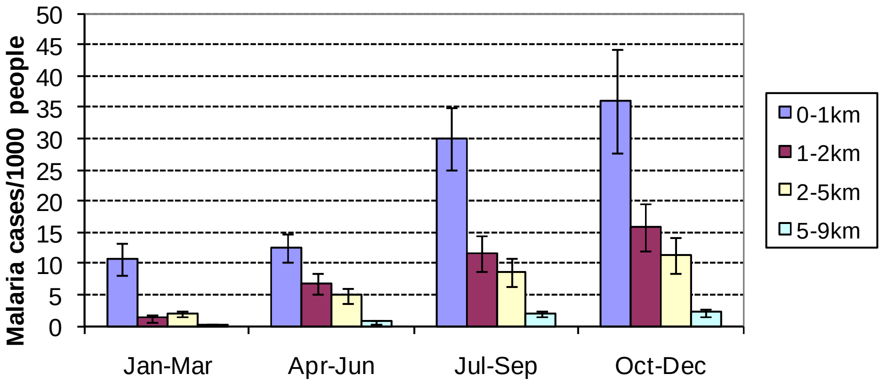


Figure 4.3. Seasonal distribution of malaria cases at different distances from the Koka reservoir (vertical bars indicate 95% confidence intervals)

4.4.2 Impact of the reservoir on vector abundance

Among the mosquito larval habitats surveyed, reservoir shoreline puddles and seepage at the base of the dam were the major *Anopheles* breeding habitats, accounting for three-quarters of the total positive larval sites in the reservoir villages. In the control villages, both rain pools and agricultural field puddles, formed during the wet season, were important *Anopheles* breeding sites. Seasonal variations in the number of positive *Anopheles* larval sites were evident in all study villages. The number of positive larval sites increased following the onset of the main rainy season in June and peaked between August and October. The mean number of positive larval sites was 6.5-times higher in reservoir villages than in the control villages and higher larval density was recorded in the reservoir villages (Table 4.2).

Table 4.2. Summary of the entomological survey in the vicinity of the Koka reservoir, Ethiopia (Aug 2006 – Dec 2007).

Parameters	Reservoir Villages			Control Villages	
	n[a]	95%CI[b]	P-value[c]	n	95%CI
Total anopheles larvae collected	2531	-	-	539	-
Mean no. of positive larval sites	15.2	9.3-21.1	<0.0001	2.3	0.5-4.1
Mean no. of larvae per 100 dips	33.1	19.8	<0.0001	9.8	3.1-16.5
Total adult *Anopheles* collected	2514	-	-	438	-
Mean no. adults/trap/night	5.2	2.9-7.5	<0.001	0.9	0.3-1.5

[a]n – number collected (or surveyed); [b]CI - Confidence Interval; [c]P – significance test at 0.05 for the difference between the reservoir and control villages.

About five-times more *Anopheles* larvae were collected in reservoir villages (n = 2,531) than in the control villages (n = 539) during the study period. Four *Anopheles* species were identified: *An*. *arabiensis*, *An*. *pharoensis*, *An*. *coustani* and *An*. *funestus*. Among them, *An*. *arabiensis* (53%) and *An*. *pharoensis* (31.3%) were the major species. In reservoir villages, a large proportion of larval *An*. *arabiensis* (65.3%) and *An*. *pharoensis* (76.1%) were obtained from shoreline puddles and seepage pools at the base of the dam. In the control villages, these species were mainly found in temporary pools (i.e. rain pools and agricultural field puddles) formed during the main wet season. Overall, the two prominent malaria vectors (i.e. *An*. *arabiensis* and *An*. *pharoensis*) utilized reservoir-associated pools for breeding throughout the year, with peak larval densities during and immediately after the main rainy season.

A total of 2,952 adult anophelines was collected during the study period, of which 85.2% and 14.8% were from the reservoir and control villages, respectively (Table 4.2). *Anopheles arabiensis* and *An*. *pharoensis* were the major species, comprising 55.3% and 29.8% of the total adult collections, respectively. The density of *Anopheles* mosquitoes was significantly higher in the reservoir villages than in the control villages (Figure 4.4). Indoor and outdoor mosquito collections showed insignificant difference in the density of *An. arabiensis.* The other *Anopheles* species were collected primarily from outdoor traps.

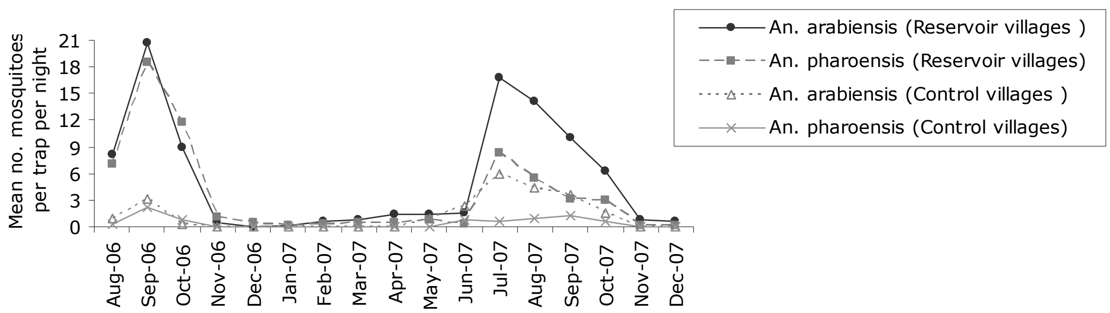


Figure 4.4. Monthly vector density (mean number of mosquitoes/trap/night) in the vicinity of Koka reservoir between August 2006 and December 2007

4.4.3 Impact of reservoir water-level change on malaria and vector abundance

Multivariate analyses were conducted to determine the relative importance of changes in reservoir water levels (both rising and falling) over and above the absolute water level and climatic factors on malaria case rates. The model that explained the highest proportion of variation (adjusted R^2 = 0.62) is for the reservoir village Ejersa. For the other reservoir village, Siree Robe, the best model explains a much smaller proportion of the variation (adjusted R^2 = 0.32). For both reservoir villages the most significant explanatory variable was found to be water level change lagged by two months. For the control villages (Gudedo and Kuma) explanatory models explain less than half the variation; adjusted R^2 = 0.24 and 0.46 respectively. In common with the reservoir villages, for both control villages the most significant explanatory variable was found to be lagged water level change, although the lag for Gudedo was one rather than two months. Both the control villages are more than 6 km from the reservoir (i.e. significantly more than the maximum flying distance of mosquitoes (Ribeiro et al, 1996)) and so will not be colonized by mosquitoes from the reservoir. Consequently, there is no obvious biophysical explanation why changes in reservoir water levels would affect malaria case rates in these villages. However, there is a high correlation (r = 0.74) between water level change and rainfall (i.e. broadly water levels rise as a consequence of rainfall and drop when rainfall ceases) which confounds the analyses.

Data collected in the entomological study between August 2006 and December 2007 were used to investigate relationships between changes in reservoir water levels and both larvae in shoreline puddles and adult mosquitoes in the reservoir villages. In a similar way to the analyses conducted with malaria case data, multiple linear regression (step-wise) analyses were conducted to determine the relative importance of changes in reservoir water level (both rising and falling), over and above the absolute water level and climatic variables (i.e. rainfall, maximum and minimum temperature). However, because the entomological survey was conducted over a period of just 17-months, far fewer data were available, than for the analyses of malaria case data obtained over 13 years. For the non-reservoir villages the proportion of observations with zero larvae and zero adult mosquitoes collected was high and there was insufficient variation in the non-zero observations to determine a relationship with explanatory variables. Consequently, analyses were not conducted for the control villages.

For larval density, the models that explained the highest proportion of variation for Siree Robe and Ejersa, each contained just one variable. However, for Siree Robe this was mean monthly water level lagged by two-months and for Ejersa it was rainfall lagged by one month. In neither case was water-level change selected. Interestingly, for adult mosquito density water-level change was selected as the key variable for both villages.

The above results are likely due to water level change, mean monthly water level and rainfall being highly correlated. To investigate this, the specific relationship between the rate of water level change and total larvae abundance (i.e. the total number of larvae counted in the shoreline puddles of both Ejersa and Siree Robe) was investigated. Visual inspection of scatter plots indicated a potential linear relationship with falling water levels but no relationship with rising water levels. A simple linear regression fitted to only falling water levels resulted in an R^2 of 0.44. This indicates that the more rapidly the water-levels drop the lower the larval abundance (Figure 4.5). Although there is a great deal of scatter, the regression equation suggests that broadly, water levels falling at a rate of -10 mmd^{-1} and -20 mmd^{-1} respectively, are associated with larval abundances approximately 5x and 2.5x greater than when water levels fall at -25 mmd^{-1}.

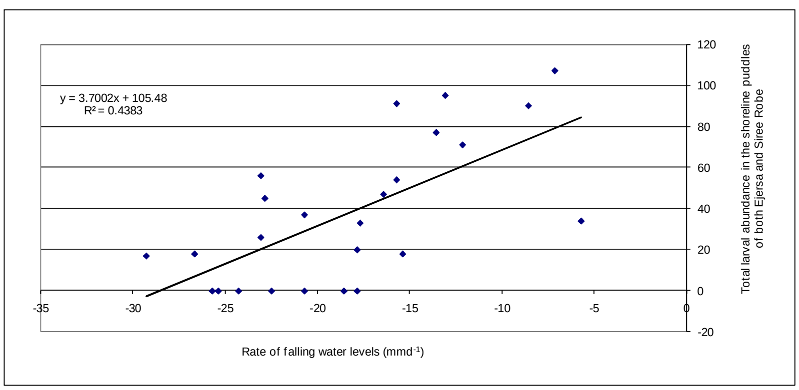


Figure 4.5. Graph showing a potential relationship between total larval abundance in shoreline puddles at Ejersa and Siree Robe and the rate of falling water levels.

4.5 Discussion

This study's general finding is that the intensified malaria transmission in communities located close to the Koka reservoir (Lautze et al. 2007) results from increased vector abundance, due largely to breeding sites directly associated with the permanent water body. This is consistent with evidence from permanent water bodies elsewhere in Africa (Carrara et al. 1990; Keiser et al. 2005; Yohannes et al. 2005). The present findings clearly indicate that reservoir water-levels affect malaria transmission, particularly during the period of high water-levels, which coincide with the peak malaria transmission season. Shoreline puddles were the major breeding grounds for malaria vector mosquitoes. For mosquito larvae, these puddles were highly productive between September and November. During this period, the puddles are favorable for mosquito breeding because they are sustained for longer than the time needed for larval development (ca. 15 days). This finding on the seasonality of vector abundance is consistent with the malaria transmission trends around Koka.

The majority of adult mosquitoes in the reservoir communities were caught outdoors indicating that they tend to feed outdoors. The outdoor questing tendencies of vectors around the Koka reservoir may be driven, in part, by the frequent use of indoor residual spraying to offset the perceived malaria threat around the reservoir. Evidence exists from the region that anophelines may modify their behavior to feed mainly outdoors in response to repeated indoor spraying with insecticides (Ameneshewa and Service 1996). Further, because some mosquitoes feed early in the evening (Kibret 2008), the potential contributions from conventional malaria prevention strategies (e.g., bed net distribution) may be limited. Consequently, malaria suppression efforts near impounded water may benefit greatly from environmental management. Since seasonal variation in malaria transmission around Koka appears to be a function of the impounded water-level, disrupting larval development in shoreline sites, when the reservoir is full, could comprise a valuable component of an integrated malaria control strategy. More research is required, but the results from this component of the project suggest that manipulation of reservoir water-levels, during periods of peak transmission, could play a key role in improving malaria interventions in the area. Ongoing modeling studies are being undertaken to ascertain the implications for hydropower and irrigation, of implementing a malaria control strategy based on drawing down the reservoir at a minimum rate of 20 mm d^{-1} at the end of the wet season (i.e. months September to November) (Reis, forthcoming).

4.6 Conclusion

Given the large number of dams to be built in sub-Saharan Africa in the near future, further research is required to better predict the likely public health implications in different hydro-ecological settings and to assess the general feasibility of using water-level manipulation to reduce adverse health impacts. More research is required to gain insight into the processes and mechanisms operating and to be able to predict under exactly what conditions such control measures are likely to be both successful and cost-effective.

Further details of this component of the project are presented in Lautze (2007), Lautze et al. (2007), Mellese (2008), Tesfaye (2008) and Kibret et al. (2009).

5 Objective 5: to illustrate how DSSs can be used to provide preliminary estimates of environmental flows in data scarce regions

5.1 Background

Recognizing the indispensable role of rivers in national economic development and establishing environmentally adequate and socially acceptable limits of their exploitation is of utmost importance. One of the major challenges for sustainable water resource management is to assess how much water can be taken from a river before its ability to meet social, ecological and economic needs declines.

One of the dams constructed in Ethiopia, and the only one currently located on the main stem of the Blue Nile River, is the Chara Chara weir, which regulates flow at the outlet of Lake Tana for hydropower production,35km downstream at Tis Abay (see objective 1 for further details). The principal tributary between the lake and Tis Abay is the Andassa River (Figure 5.1).

Prior to construction of the Chara Chara weir, in 1995, the Tis Abbay I power station (capacity 11.4 MW) relied entirely on diversion of the natural flow of the river immediately upstream of the Tis Issat Falls. The power plant makes use of the natural 46 m head of the Falls. Initially the Chara Chara weir comprised only two gates, each with a capacity of 70 m^3s^{-1}. However, to improve regulation an additional five gates, also of capacity 70 m^3s^{-1}, were added to the weir in 2001. In the same year, a second power station (capacity 73 MW) was constructed at Tis Abbay. Since then the weir has been operated by EEPCo to maximize power production from both power stations.

The Chara Chara Weir was constructed before legislation requiring an environmental impact assessment be conducted (i.e. proclamation number 9/1995 passed in 2002), nevertheless an EIA was conducted. As part of this an attempt was made to estimate flow requirements over the Tis Issat Falls. However, the focus was on tourist needs and so this evaluation was based primarily on the appearance of the Falls under different flow regimes (Bellier *et al.*, 1997). The maximum flows were recommended, not for the wet season when flows would naturally be highest, but to make the Falls look most dramatic during the peak tourist season from December to February.

In this component of the project we conducted a preliminary environmental flow investigation, to estimate environmental flow requirements in the reach of the Abay River that includes the Tis Issat Falls. The estimates derived were compared with the actual flows since the weir became fully operational in 2001. This study is believed to be one of the first attempts to rigorously quantify a full range of environmental flow requirements (both high and low flows) and to assess the impact of flow regulation, anywhere on the Blue Nile River.

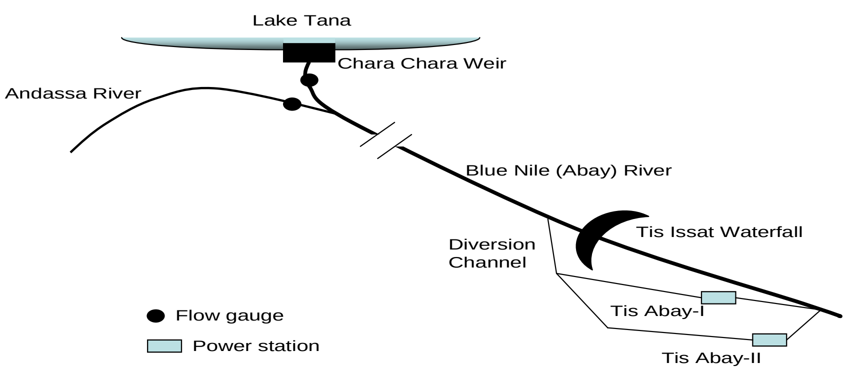


Figure 5.1. Schematic of the system (not to scale)

5.2 Methods

This component of the project comprised two elements. First, analyses of flow data to quantify the changes in the hydrological regime of the river, arising from operation of the weir and diversions to the power stations. Second, an evaluation of the environmental flow requirements through application of the South African Desktop Reserve Model (DRM) (Hughes and Hannart, 2003).

5.2.1 Evaluating the change in the hydrological regime

A gauging station, located immediately downstream of the outlet from Lake Tana, has operated continuously since 1959. The intermediate catchment between the Chara Chara weir and the diversion to the Tis Abay power stations has an area of 1,094 km^2. The principal tributary between the lake and Tis Abay is the Andassa River, which is gauged just upstream of its confluence with the Blue Nile (Figure 5.1). The catchment area at the Andassa River gauging station (which has also operated since 1959) is 573 km^2.

Time series of monthly flow data, were obtained from the Ministry of Water Resources for both gauging stations from January 1959 to December 2006. Daily flow series were obtained for both stations from January 1973 to December 2006. An estimate of the contribution from the ungauged portion of catchment downstream of the lake outlet was derived by multiplying the flow series derived from the Andassa gauge using an area-weighting. The flows downstream of Lake Tana were added to the flows from the outlet to provide an estimate of the total flow at the diversion to the power stations. Turbine discharge data for both Tis Abay-I and Tis Abay-II power stations were obtained from EEPCo and used to estimate the monthly flows diverted to produce electricity as well as the water remaining in the river to flow over the Falls.

Analyses of flows were conducted over three time periods: May 1959 to April 1996, May 1996 to December 2000 and January 2001 to December 2006. These periods correspond to different levels of regulation of the Lake Tana outflow (Table 5.1). Standard hydrological techniques, including flow frequency analyses and the development of flow duration curves (using the daily data) (Gustard *et al*., 1992) were used to compare the flow regimes in each of these periods.

Table 5.1. Periods of different flow regulation from Lake Tana

Period	**Description**
May 1959 - April 1996	No regulation of outflow from Lake Tana. Diversions to the Tis Abay-I power station commenced in January 1964.
May 1996 – December 2000	Two-gate Chara Chara weir becomes operational in May 1996. Weir operated to regulate flow to the Tis-Abay-I power station.
January 2001 – December 2006	Five new gates constructed and new weir becomes operational in January 2001. Weir operated to regulate flow to both the Tis Abay-I and Tis Abay-II power stations.

5.2.2 Estimating environmental flows

In recent years, there has been a rapid proliferation of methods for estimating environmental flows, ranging from relatively simple, low-confidence, desk-top approaches, to resource-intensive, high-confidence approaches. The comprehensive methods are based on detailed multi-disciplinary studies, which often involve expert discussions and collection of large amounts of geo-morphological and ecological data (e.g., King and Louw, 1998). Typically they take many months, sometimes years, to complete.

A key constraint to the application of comprehensive methods, particularly in developing countries, is lack of data linking ecological conditions to specific flows. To compensate for this, several methods of estimating environmental flows have been developed that are based solely on hydrological indices derived from historical data. One such method is the Desktop Reserve Model (DRM). This is intended to quantify environmental flow requirements when a rapid appraisal is needed and data availability is limited (Hughes and Hannart, 2003). It should be viewed only as a preliminary step in deriving environmental flows. Ideally, flow estimates generated by the model should be refined based on far more extensive and detailed ecological and livelihood studies that quantify the links between changing river flows and natural resources and hence the likely impacts for riparian people.

The DRM is built on the concepts of the building block method, which was developed by South African scientists over several years (King *et al*., 2000), and is widely recognised as a scientifically legitimate approach to setting environmental flow requirements (Hughes and Hannart, 2003). The Building Block Method is developed on the premise that, under natural conditions, different flows play different roles in the ecological functioning of a river. Consequently, to ensure sustainability, it is necessary to retain key elements of natural flow variation. Hence, so called Building Blocks are different components of flow which, when combined, comprise a regime that facilitates the maintenance of the river in a pre-specified condition. The flow "blocks" comprise low discharges, as well as high discharges, required for channel maintenance. Different estimates are derived for "normal years" and "drought years". The flow needs in normal years are referred to as "maintenance requirements". The flow needs in drought years are referred to as "drought requirements" (Hughes, 2001). The DRM provides estimates of these building blocks for both maintenance and drought requirements for each month of the year.

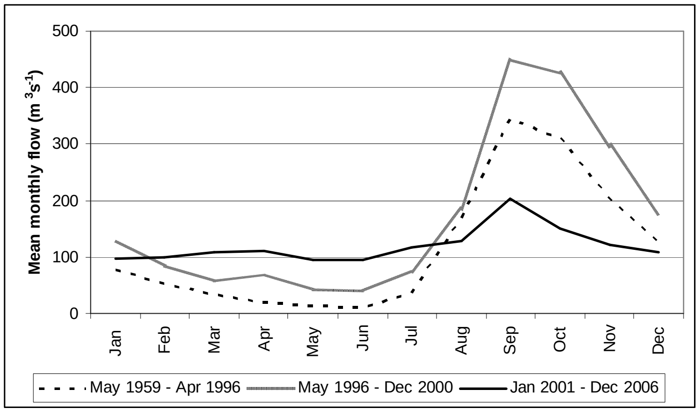
The DRM has been used extensively in South Africa. Its use in other African countries is limited, but it has been applied in Swaziland, Zimbabwe, Mozambique (Hughes and Hannart, 2003) and Tanzania (Kashaigili et al. 2007). The model comprises empirically derived statistical relationships developed through an analysis of comprehensive environmental flow studies. This found that rivers with more stable flow regimes have relatively higher flow requirements than rivers with more variable flow regimes. This is because in highly variable flow regimes the biota will have adjusted to relative scarcity of water, whilst in more reliably flowing rivers, the biota are more sensitive to reductions in flow (Hughes and Hannart, 2003).

In South Africa, rivers are classified in relation to a desired ecological condition, and flow requirements set accordingly. Six management classes are defined, ranging from A to F. Class A rivers are largely unmodified and natural and class F rivers are extremely modified and highly degraded (DWAF, 1999). Classes E and F are deemed ecologically unsustainable so class D (i.e. largely modified) is the lowest allowed "target" for future status. This classification system is used in conjunction with the Building Block Method and flow requirements are computed accordingly; the higher the class, the more water is allocated for ecosystem maintenance and the greater the range of flow variability preserved (DWAF, 1999). In the current study, to reflect the importance of water abstractions for hydropower production, the desired ecological condition of the Blue Nile was set as C/D (i.e., moderately to largely modified).

5.3 Results

5.3.1 Impacts of flow regulation

Figure 5.2 shows the mean monthly flow, measured immediately downstream of the Chara Chara Weir, for the three periods investigated. The May 1959 to April 1996 results indicate the extreme seasonal variability in the natural flow regime, ranging from a mean of 346 m^3s^{-1} in September to just 12 m^3s^{-1} in June. On average only 12% of the natural discharge from the lake occurred in the 5 months February to June. In the period May 1996 to December 2000, both wet season flows and dry season flows were significantly higher than occurred in the previous period. The higher dry season flows were a consequence of partial flow regulation by the two-gate Chara Chara weir. The higher wet season flows were a consequence of above average rainfall in these years, particularly in 1998. Mean annual flow in 1998 (196.0 m^3s^{-1}; 6182 Mm^3y^{-1}) was the highest annual discharge measured in the whole 48 year record. The results for the period from January 2001 to December 2006, illustrate the much higher dry season flows and reduced wet season flows arising as a consequence of the full flow regulation by the Chara Chara Weir. As a consequence of regulation there is much less seasonal variability in flow from the lake. After 2001, 43% of the discharge from the lake occurred in the 5 months February to June.

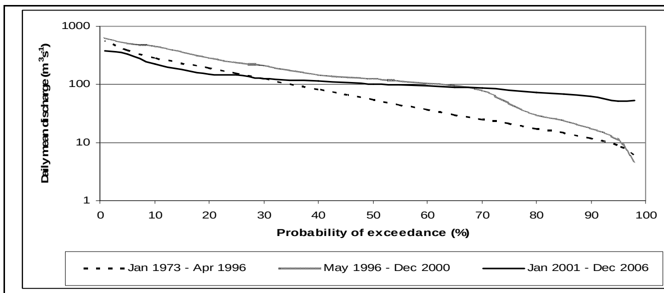


	May 1959-Apr 1996	May 1996-Dec 2000	Jan 2001-Dec 2006
Jan	77.4	127.4	97.6
Feb	53.2	84.0	98.7
Mar	33.4	57.3	109.3
Apr	20.2	69.1	109.9
May	12.9	41.4	94.3
Jun	11.5	39.1	95.0
Jul	34.8	75.5	116.5
Aug	168.8	184.6	127.8
Sep	345.9	449.0	204.4
Oct	309.7	423.8	150.8
Nov	200.7	297.4	122.6
Dec	125.6	177.7	109.3
MAF[a]	116.3	169.0	119.7

[a]MAF = mean annual flow

Figure 5.2. Mean monthly flow from Lake Tana for three periods of different flow regulation

Flow duration curves, which show the percent of time that a specified discharge is equaled or exceeded, were derived for the period for which daily data were available (i.e., from January 1973 to December 2006) (Figure 5.3). These confirm the significant impact of the new seven-gate Chara Chara weir on flow from the lake. Since 2001, there has been a significant increase in flows lower than Q_{50} (i.e. the mean daily flow exceeded 50% of the time) and a significant decrease in flows above Q_{50}. Q_{95} and Q_{90} increased from 9.0 m^3s^{-1} and 11.9 m^3s^{-1} to 59.3 m^3s^{-1} and 64.5 m^3s^{-1} respectively. In contrast Q_{10} and Q_5 decreased from 285.8 m^3s^{-1} and 382.6 m^3s^{-1} to 195.5 m^3s^{-1} and 246.3 m^3s^{-1} respectively.



	Jan 1973-Apr 1996	May 1996-Dec 2000	Jan 2001-Dec 2006
Q_{95}	9.0	11.3	59.3
Q_{90}	11.9	17.5	64.5
Q_{70}	21.0	49.2	79.3
Q_{50}	54.7	126.2	101.9
Q_{25}	155.1	239.3	136.6
Q_{10}	285.8	449.0	195.5
Q_5	382.6	513.0	246.3

Figure 5.3. Flow duration curves for the Blue Nile River, at the outlet from Lake Tana. Note that flows are shown on a log scale to illustrate clearly the differences in low flows in the three different time periods.

5.3.2 Impact of hydropower diversions

The data provided by EEPCo indicate that when only the Tis Abay-I power station was operational (i.e. between 1964 and 2000) average annual turbine discharge was just 192 Mm^3y^{-1} (i.e. 6.1 m^3s^{-1}). Throughout this period just 4.5% of the average annual discharge at Tis Abay (4,227 Mm^3) was diverted. Since 2001, when Tis Abay-II came on line, the average annual turbine discharge has increased to 3,090 Mm^3y^{-1} (i.e. 97.9 m^3s^{-1}). This equates to 72% of the average annual discharge at Tis Abay (4,306 Mm^3y^{-1}) between 2001 and 2006.

Diversions to the original Tis Abay-I power station had very little impact on the flows over the Tis Issat waterfall. Between 1964 and 2000 average annual discharge over the Falls is estimated to have been 128 m^3s^{-1} (i.e. 4,040 Mm^3y^{-1}). By comparison, between 2001 and 2006 (after the construction of second power station) the average annual discharge over the Falls is estimated to have been just 41 m^3s^{-1} (i.e. 1,305 Mm^3y^{-1}), with a minimum of just 4.7 m^3s^{-1} (i.e. 147 Mm^3y^{-1}) in 2004 and less than 12m^3s^{-1} (i.e. 378 Mm^3y^{-1}) in both 2003 and 2005. Between 2001 and 2006, in many months, the mean discharge was less than 50% what it was prior to 2001 (Figure 5.4).

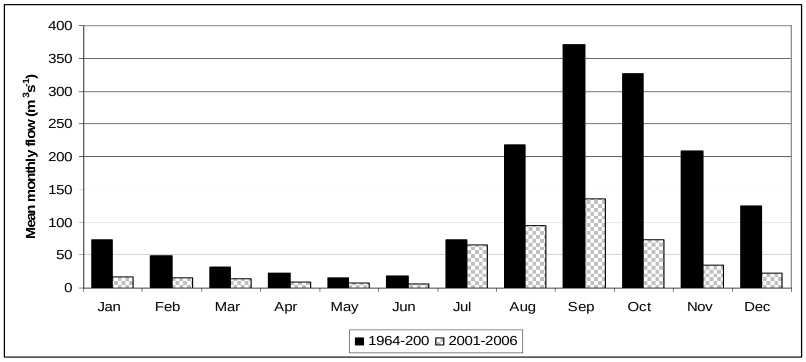


Figure 5.4. Comparison of flow over the Tis Issat Falls for the periods 1964-2000 and 2001-2006

5.3.3 Environmental flow requirements

Results from the DRM indicate that to maintain the river at class C/D requires an average environmental flow allocation of 862 Mm^3y^{-1} (i.e., equivalent to 22% of the natural mean annual discharge) as shown in (Table 5.2). This is the average annual "maintenance flow" calculated from the mean of both the maintenance low flows (i.e., 626 Mm^3y^{-1}) and maintenance high flows (i.e., 236 Mm^3y^{-1}). The drought flows correspond to 11% of the mean annual flow (i.e., 440 Mm^3y^{-1}).

The total allocation estimated from the DRM is slightly less than the total estimated in the Chara Chara EIA, which equated to an average of 995 Mm^3y^{-1} (Bellier *et al.*, 1997). However, the distribution of flows is very different (Figure 5.5), reflecting a much more natural distribution of flow than proposed in the EIA which, as discussed above, focused primarily on ensuring high flows over the Falls during the peak tourist season (i.e. December and January).

For the period 2001 to 2006, average annual flows over the Falls (i.e., 1,305 Mm^3y^{-1}) exceeded the annual total maintenance flow requirements predicted by the model (i.e., 862 Mm^3y^{-1}). However, more detailed analysis shows that in most months average flows were significantly less than the environmental flow requirements predicted by the model. For several months average flows were less than 70% of the estimated requirement (Table 5.3). Only in months July to October (i.e., wet season months) did the average flow over the period 2001 to 2006 exceed the recommendation of the DRM (Table 5.3; Figure 5.5). This suggests that, in recent years, dry season flows have been insufficient to maintain even basic ecological functioning of this reach of the Abay River. Furthermore, even though the average over the period exceeds the DRM recommendation, in several years even the wet season flow was a lot less than recommended. For example, in September and October 2005, flows over the Falls were estimated to have been just 44 $Mm^3month^{-1}$and 7.6 Mm^3month^{-1} respectively; less than even the recommended minimum drought flows.

Table 5.2. Summary output from the desktop reserve model applied to the reach of the Tis Issat Falls based on 1960-1995 monthly flow series

Annual Flows (Mm^3y^{-1}or index values)						
MAR	= 4017		Total Environmental flow		= 862 (22% MAF)	
S.D.	= 1293		Maintenance Low flow		= 626 (16% MAF)	
CV	= 0.322		Drought Low flow		= 440 (11% MAF)	
BFI	= 0.37		Maintenance High flow		= 236 (6% MAF)	

	Observed flow (Mm^3 $month^{-1}$)		Environmental flow requirement (Mm^3 $month^{-1}$)			
			Maintenance flows			Drought flows
Month	Mean	CV	Low	High	Total	
Jan	217	0.35	68	0	68	48
Feb	135	0.34	56	0	56	39
Mar	97	0.31	42	0	42	30
Apr	58	0.29	28	0	28	20
May	42	0.35	22	0	22	16
Jun	44	0.46	20	1	21	10
Jul	180	0.43	27	11	39	20
Aug	590	0.38	51	33	83	36
Sep	946	0.39	77	115	192	54
Oct	839	0.36	84	33	117	59
Nov	526	0.33	78	31	109	55
Dec	345	0.33	74	12	86	52

Table 5.3. Comparison of environmental flow requirements computed by the DRM and observed mean monthly flows in the river reach that includes the Tis Issat Falls, between 2001 and 2006.

Month	Total maintenance requirements	Observed flows	Ratio of observed to environmental flow requirement
	Mm^3month^{-1}	Mm^3month^{-1}	
Jan	68	44	0.64
Feb	56	36	0.64
Mar	42	36	0.85
Apr	28	22	0.81
May	23	21	0.96
Jun	21	16	0.76
Jul	39	178	4.57
Aug	83	252	3.03
Sep	192	352	1.83
Oct	117	196	1.68
Nov	109	92	0.85
Dec	86	61	0.71
Annual	862	1,305	

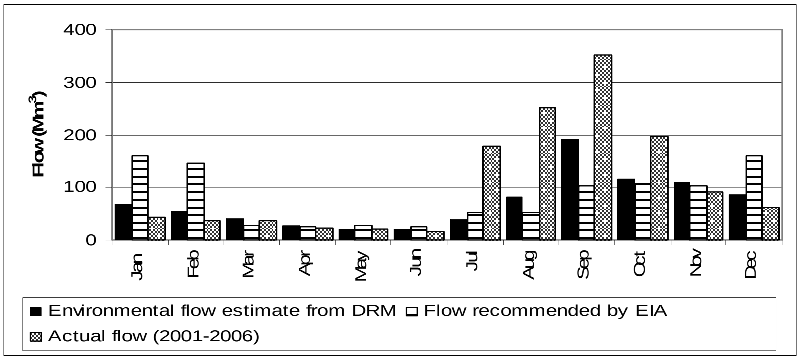


Figure 5.5. Comparison of mean monthly environmental flow requirement estimated using the DRM, with the recommendation of the EIA and the actual flows over the Tis Issat Falls

5.4 Discussion

In recent years the Tis Abay power stations have been vital for electricity production and have contributed significantly to the economic development of Ethiopia. However, operation of the Chara Chara weir has altered the flow regime of the Abay River. Between the outlet from Lake Tana and Tis Abay, the regulation has significantly increased dry season, and significantly decreased wet season, flows. Since 2001, flows in the reach containing the Tis Issat Falls have been significantly reduced, in both the wet and dry seasons, as a consequence of diversions to the power stations. Although no ecological surveys have been conducted there is little doubt that these changes in flows will have had consequences for many species including aquatic macrophytes, benthic organisms and fish (Seddon 2000; Staissny 1996). Although the consequences of these changes may not be apparent for many decades, it is also possible that they will modify not just river biota but also channel morphology and substrate composition. In addition to ecological impacts, the changes in flow regime have also had social impacts (see objective 1).

Because the DRM is underpinned by empirical equations developed specifically for South Africa, and is only intended to be a "low-confidence" approach, the results must be treated with caution and should not be used for detailed planning. Nonetheless, despite the limitations, in the absence of quantitative information on the relationships between flow and the ecological functioning of the river ecosystem, they are a valuable first estimate of the environmental flow requirements in this reach of the river. Despite the caveats, the results suggest that present flows are, almost certainly, a long-way below the minimum required to maintain even the basic ecological functioning of the river reach that contains the Falls and so the long-term consequences for both the environment and the people living in the vicinity of the reach may be severe. Over the long-term it may be better to forego some financial benefits in order to maintain the basic ecosystem functions of the river.

To improve the environmental flow estimates detailed studies need to be undertaken to investigate the ecological sensitivity of the river to flow modification throughout its length from the Lake Tana outlet to the Falls and, indeed, downstream of the point where the diverted flows are returned to the river. The impact of maintaining environmental flows on water-levels and, hence, the ecology of Lake Tana should be very carefully assessed. Furthermore, in order to make informed decisions about the desired ecological state of the river, both the implications for hydropower production and the social implications (positive and negative) of different flow regimes should be carefully evaluated. It is very important that, as far as possible, such evaluations go beyond simple cost-benefit analyses and also include intangible benefits that cannot be expressed in monetary terms. Finally, other detailed studies should be conducted at different locations on the Abay and its tributaries, and also on other rivers, to calibrate and improve the DRM for more general application on the Nile and elsewhere in Ethiopia.

5.5 Conclusion

Environmental flows are increasingly recognized as a critical component of sustainable water resources management. However, in Ethiopia, in common with many developing countries, their estimation and implementation is impeded by lack of data and expertise. Given the dam building program currently being planned and implemented in Ethiopia, the country would be wise to initiate a capacity building program in environmental flow assessment.

Further details of this component of the project are presented in Shiferaw (2007), Shiferaw and McCartney (2008), Shiferaw et al. (2008) and McCartney et al. (2009).

6 Objective 6: to illustrate how DSSs can be used to evaluate the impact of planned large dam construction for hydropower and irrigation

6.1 Background

The Lake Tana catchment, located in the headwaters of the Blue Nile (Figure 1.1), has been identified as a region for significant infrastructure investment in the near future (see objective 1). The intention is to stimulate economic growth and reduce poverty through the development of hydropower and a number of irrigation schemes (MoFED, 2006). However, the environmental implications of this development and specifically the impact on lake water-levels have not been fully evaluated. Such an evaluation is crucial because the lake is important to the livelihoods of many people in a number of different ways. The lake and the wetlands in its vicinity are important for domestic water supply, fisheries, grazing and water for livestock, as well as reeds for boat construction. The lake is also important for water transport and as a tourist destination.

This component of the project used the Water Evaluation And Planning (WEAP) model to investigate scenarios of future water resource development in the Lake Tana catchment. The model was used to investigate both the reliability of water availability for the planned schemes and their impact on lake water levels and lake surface area. For each scenario, the implications of maintaining environmental flows downstream of the lake to the Tis Issat Falls (see objective 5) were also ascertained. For each scenario, the model was used to simulate water demand over a 36-year period of varying flow and rainfall.

6.2 The study area

Lake Tana is the largest freshwater lake in the country and the third largest in the Nile Basin. The catchment area of the lake at its outlet is 15,321 km^2 of which about 20% is covered by the lake itself. More than 40 rivers and streams flow into the lake, but 93% of the water comes from four major rivers: Gilgel Abbay, Ribb, Gumara and Megech. The mean annual inflow to the lake is estimated to be 158 m^{3}s^{-1} (i.e. 4,986 Mm^{3}y^{-1}). The mean annual outflow is estimated to be 119 m^{3}s^{-1} (i.e. 3,753 Mm^{3}y^{-1}) (SMEC 2008). Under natural conditions, discharge from the lake is closely linked to rainfall and there is considerable seasonal and inter-annual variability (Kebede et al. 2006). Naturally, the annual water level fluctuations varied between 1785.75 and 1786.36 masl.

The total population in the lake catchment was estimated to be in excess of 3 million in 2007 (CSA 2003). The largest city on the lake shore, Bahir Dar, has a population of over 200,000 and at least 15,000 people are believed to live on the 37 islands in the lake. The majority of the population depend for their livelihoods on rainfed agriculture. Despite the huge potential, there is very little irrigated agriculture in the basin. Of the estimated

517,500 ha of cultivated land, traditional small-scale irrigation is practiced on less than 500 ha and currently there is no large-scale irrigation, though the Koga irrigation scheme is nearing completion. Recession cropping, mainly for maize and rice, is carried out in the wetlands adjacent to the lake shore.

The Chara Chara weir regulates water storage in Lake Tana over a 3 m range of water levels from 1784 masl to 1787 masl. The active storage of the lake between these levels is about 9,100 Mm^3, which represents approximately 2.4x the average annual outflow. The regulation for power production has modified the natural lake-level regime, resulting in reduced seasonal but greater inter-annual variability (Figure 6.1). The lowest level ever recorded was in June, 2003. This was a drought year in much of Ethiopia and hydropower production was constrained in many places. In an attempt to maintain electricity supplies production at Tis Abay was maximized and as result lake levels declined sharply (Gebre et al. 2007b). As a consequence of the low lake levels in 2003, navigation ceased for approximately four months (i.e. when lake levels dropped below 1785 masl, the minimum level at which ships can currently operate), large areas of papyrus reed were destroyed, there was significant encroachment of agriculture on the exposed lake bed and there was a decrease in fisheries production (EPLAUA 2004).

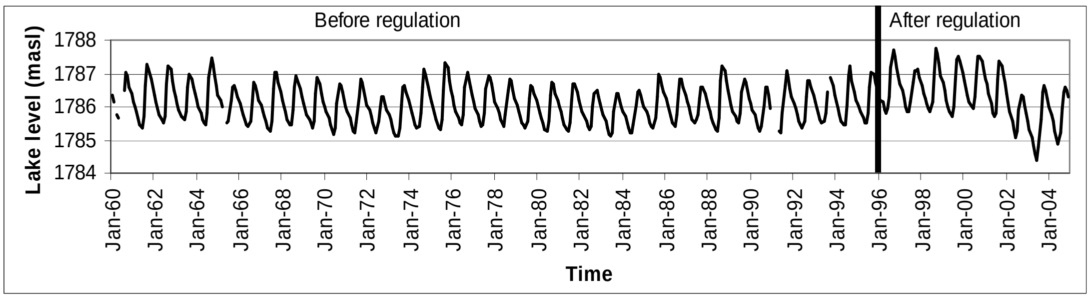


Figure 6.1.Water level fluctuations of Lake Tana before and after regulation (Source: plotted using data provided by the Ministry of Water Resources)

6.2.1 Planned water resource development

Within the Lake Tana catchment a number of water resource schemes are currently under development and planned for the future (Figure 1.1). Currently, the Tana-Beles project is under construction. This scheme involves the transfer of water from Lake Tana to the Beles River via a 12km long tunnel (Salini and Mid-day, 2006). The aim of the inter-basin transfer is to generate hydropower by exploiting the 311 m elevation difference between the lake and the Beles River. A power station, with generating capacity of 460MW, is being built on the upper Beles River. This will enable far more electricity to be generated than is currently produced in the Tis Abbay power stations. Approximately 2,985 Mm^3y^{-1} will be diverted through the tunnel each year to generate 2,310 GWh of electricity (SMEC, 2008). Both the Tis Abbay power stations will be moth-balled and only used in emergencies. Although not considered in the current study, it is planned to develop irrigation schemes downstream of the new power station to utilize the higher flows in the Beles catchment.

In addition, a number of irrigation schemes (up to approximately 60,000 ha) are planned on the main rivers flowing into Lake Tana (Table 6.1). Of these the Koga irrigation project (6,000 ha) is nearing completion and the Ribb scheme is currently under construction. For several of the other schemes detailed feasibility studies have been undertaken and planning is at an advanced stage. It is anticipated that construction of several of the dams and irrigation schemes will commence in the near future.

Table 6.1. Planned irrigation development in the Lake Tana catchment (source: BCEOM 1998; Mott MacDonald 2004b; WWDSE and ICT 2008; WWDSE and TAHAL 2008a, b)

Irrigation scheme	Irrigable area (ha)	Estimated annual gross water demand (Mm^3y^{-1})[a]	Estimated net water demand (Mm^3y^{-1})[a]	Large dam storage (Mm^3)	Stage of development
Gilgel Abbay B	12,852	104–142	88–121	563	Feasibility studies ongoing
Gumara A	14,000	115	98	59.7	Feasibility studies completed
Ribb	19,925	172–220	146–187	233.7	Under construction
Megech	7,300	63 – 98	54–83	181.9	Feasibility studies completed
Koga	6000	62	52	78.5	Under construction
NE Lake Tana	5745	50–62	43-53	Withdrawals from the lake	Pre-feasibility studies completed
NW Lake Tana	6720	54	46	Withdrawals from the lake	Identification
SW Lake Tana	5132	42	36	Withdrawals from the lake	Identification

[a]demands estimated though crop water modeling and presented in feasibility study reports. Where a range of demands is presented this reflects alternative cropping patterns. Gross minus net demand is water returned to the rivers.

6.3 Methods

6.3.1 Configuration of WEAP to the Lake Tana catchment

The WEAP model was developed by the Stockholm Environment Institute (SEI) in Boston and provides an integrated approach to simulating water systems associated with development (Yates et al. 2005). WEAP represents the system in terms of its various supply sources (e.g. rivers, inter-basin transfers and reservoirs); withdrawal, transmission and wastewater treatment facilities; ecosystem requirements, water demands (i.e., typically comprising hydropower, irrigation, domestic supply, etc.). The model essentially performs a mass balance of flow sequentially down a river system, making allowance for abstractions and inflows. The model optimizes water use in the catchment using an iterative Linear Programming algorithm, whose objective is to maximize the water delivered to demand sites, according to a set of user-defined priorities (SEI 2007).

The modeling of the Lake Tana catchment encompassed the major tributaries to the lake, upstream of the proposed dams (i.e., water that currently flows directly into the lake that will in future be affected by regulation from the dams), estimates of flows downstream of the proposed dams and total inflows on other rivers (i.e., flows that will be unaffected by the future development) and Lake Tana (Figure 6.2). Lake Tana was simulated as a reservoir. The Andassa River was also included. The model was configured to run on a monthly-time step.

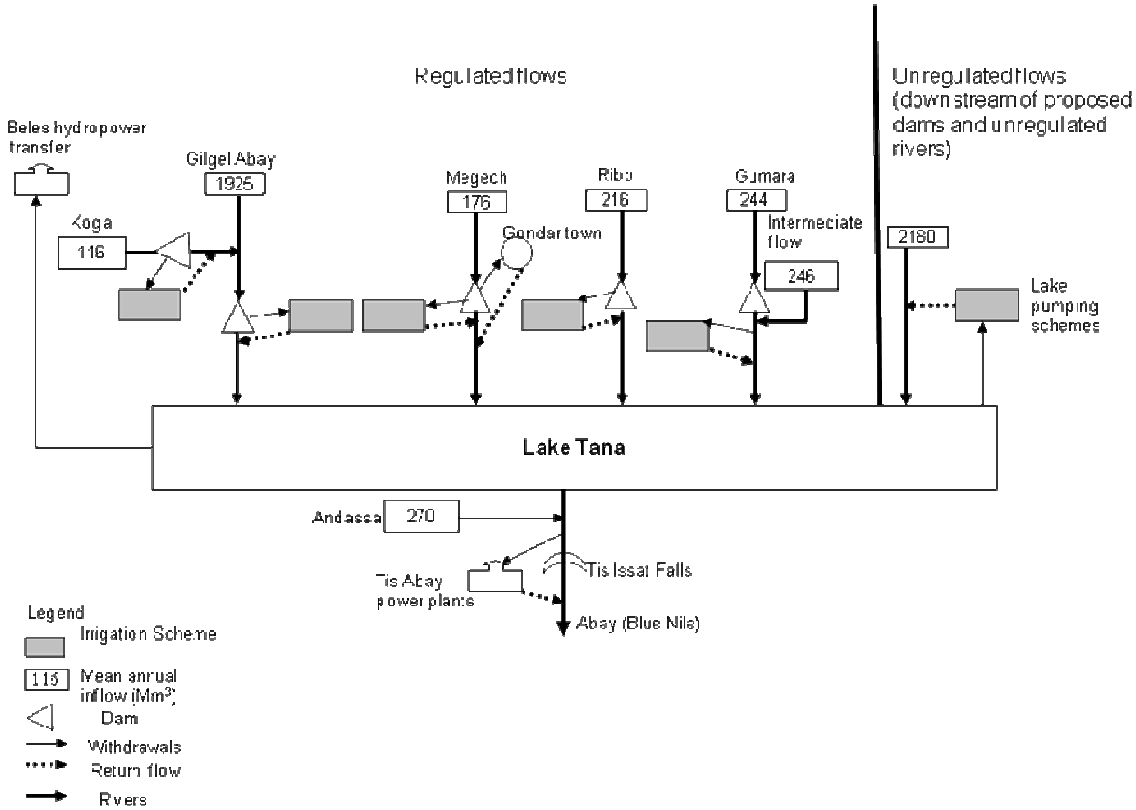


Figure 6.2. Schematic of existing and planned water demand in the Lake Tana catchment as simulated in WEAP, showing the mean annual flow upstream of the proposed irrigation dams as well as unregulated flows into the lake.

As primary input to the WEAP model the inflow series at the planned dam sites were obtained from the relevant feasibility studies for the period 1960-2004. Where necessary inflow data were augmented using area-weighted estimates from the nearest available flow gauging station. To simulate the current situation the Tis Abay hydropower plants were included as a demand node on the Abay River, downstream of the lake.

6.3.2 Description of development scenarios

Data for the various scenarios used in this study were obtained from the Abay River Basin Integrated Development Mater Plan and the feasibility studies conducted for each of the proposed schemes (BCEOM 1998; Mott MacDonald 2004; WWDSE and ICT 2008; WWDSE and TAHAL 2008a,b). These indicate how the water demand for both irrigation and hydropower is likely to change in the catchment in the future.

Four scenarios were developed based on the current stage of scheme development and hence the likelihood of full implementation (Table 6.2). Each development scenario was run for the 36 years (i.e. 1960-1995). This period was selected both because data are available and because it represents a wide range of hydrological variability. Furthermore, it represents years before construction of the Chara Chara weir and so the impact of each development scenario could be compared with the natural water-level regime of the lake.

Table 6.2. Summary of development scenarios (Source: BCEOM 1998; EEPCO database and SMEC 2008)

Scenario	**Hydropower developed**	**Irrigation schemes developed**	**Total mean annual water demand (Mm^3y^{-1})[a]**
Baseline (BS)	Tis Abay I and II	-	3,469
Ongoing Development (ODS)	Tana Beles transfer	Koga	3,047
Likely Development (LDS)	Tana Beles transfer	Koga, Megech, Ribb, Gumara and Gilgel Abay	3,621
Full Development (FDS)	Tana Beles transfer	Koga, Megech, Ribb, Gumara, Gilgel Abay and 3 schemes pumping directly from the lake	3,768

[a] water demand has been calculated using the highest crop water estimates for each of the irrigation schemes.

In all cases irrigation demand was computed based on assumed cropping patterns (i.e. encompassing crop type and percentage of command are utilized) and crop water requirements. In the feasibility studies the FAO CROPWAT program (Allen at al., 1998) was used to determine total irrigation requirement. In some cases alternative cropping patterns were simulated, but for the results presented here, the pattern that created the highest demand was selected for all schemes. In all cases allowances were made for transmission losses from canals. Return flows were estimated as 15% of the water diverted as shown in Table 6.1.

For the proposed new dams no operating rule curves are currently available. Consequently, no operating rules were incorporated within the WEAP model. This meant that the reservoirs were not drawn down to attenuate wet season floods and no restrictions were applied on abstractions as the reservoirs emptied. The one exception was Lake Tana where the operating rule was derived from the pattern of operation in recent years. Thus restrictions on draw-down were applied to reduce abstractions as lake levels dropped below 1,786 masl and to ensure levels did not drop lower than the minimum operating level of 1,784 masl. Net evaporation (i.e. evaporation minus rainfall) was computed from rainfall and evaporation data obtained from the meteorological station located closest to each reservoir.

Since it provides the highest economic returns electricity generation was designated a higher priority than irrigation. The water demand for domestic, municipal and industrial use, were not considered. This is because their impact on the water resources of the lake, both now and in the near future, is insignificant (SMEC 2008).

Each scenario was run with the flow requirement for the Tis Issat Falls as recommended in the most recent EIA conducted for the Tana-Beles transfer scheme. These flows were termed the Tana Beles Flow (TBF) requirements[7]. The scenarios were then repeated with

[7] For the baseline scenario, flows released from the Lake to provide water for the power station exceed the TBF environmental flow requirements. However, most of the water is diverted to the Tis Abay hydropower stations.

the time series of environmental flow requirements estimated in the current study using the DRM (see above). These flows were termed the Variable Environmental Flow (VEF) requirements. In both cases the proposed minimum instream flows downstream of each of the proposed irrigation dams (as identified in the feasibility studies and in all cases simply a minimum baseflow) were also included. In all cases, environmental flows were given higher priority than the hydropower production.

6.3.3 Analyses of WEAP output

For each scenario, the WEAP model was used to predict: i) the impacts on lake water-levels and lake area for each month of the 36 years simulated and ii) unmet demand for hydropower and irrigation in any month. In each scenario, the time series of lake water levels was analyzed to determine in how many months over the 36 years of simulation, the mean water-level was less than 1785 masl (i.e., the minimum required for shipping).

For unmet demand, the data were summed to calculate the annual unmet demand for each of the 36 years of simulation. Since the frequency of occurrence of unmet demand is of more interest to planners than the mean annual unmet demand, standard frequency analyses were conducted to determine the return periods for different magnitudes of shortfall. This involved fitting a statistical distribution (i.e. a two-parameter log-normal equation) to each time series of annual unmet demand. The results were then converted to assurance levels (i.e., volumes of water that can be guaranteed with different degrees of certainty). For each return period estimated, this was done by subtracting the shortfall from the demand (i.e., to give the volume that could be guaranteed) and converting the return period to a level of assurance. For example, return periods of two, five and 100 years correspond to assurance levels of 50, 80, and 99 percent, respectively. For the hydropower the volumes of unmet water demand were converted to shortfalls in electricity produced, so that assured levels of electricity generation (i.e. $GWhy^{-1}$) could be computed.

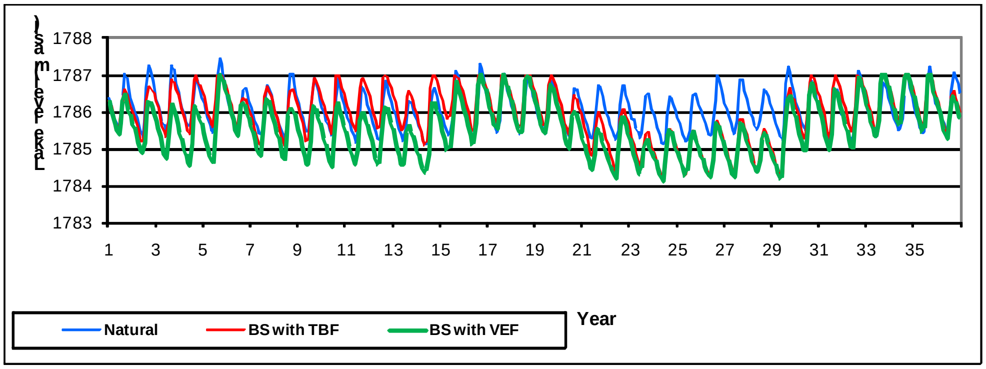
There is always some uncertainty associated with fitting statistical distributions. In this study this was particularly the case for those series in which failure to meet demand occurred in only a few years of the 36-year series. Consequently, the assurance levels are not precise, but in each case are indicative of the probability of satisfying demand in any year.

6.4 Results

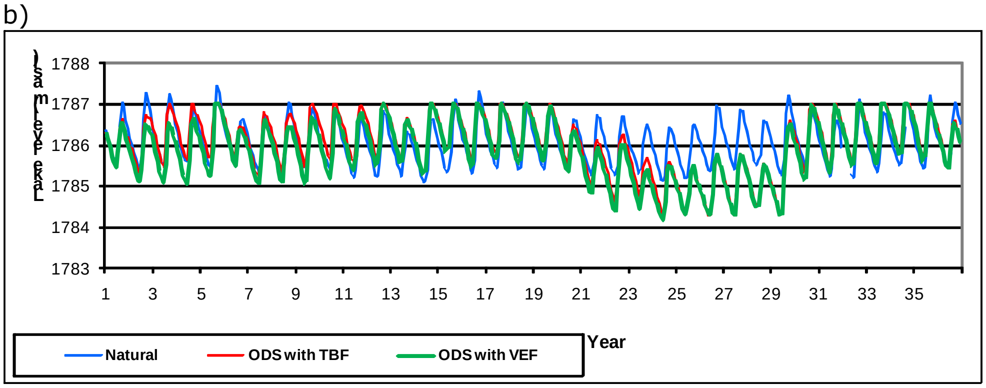
Figure 6.3 presents a comparison of the time series of simulated lake levels for all scenarios with the natural condition, both with the downstream TBF and the VEF included. Table 6.3 summarizes the results of each scenario. The results indicate the decline in mean annual lake levels, and consequently lake area, as the water resource development in the catchment increases.

To ensure a TBF over the Falls, for the baseline scenario the location of the TBF requirement was moved from immediately below the dam to the location of the waterfall.

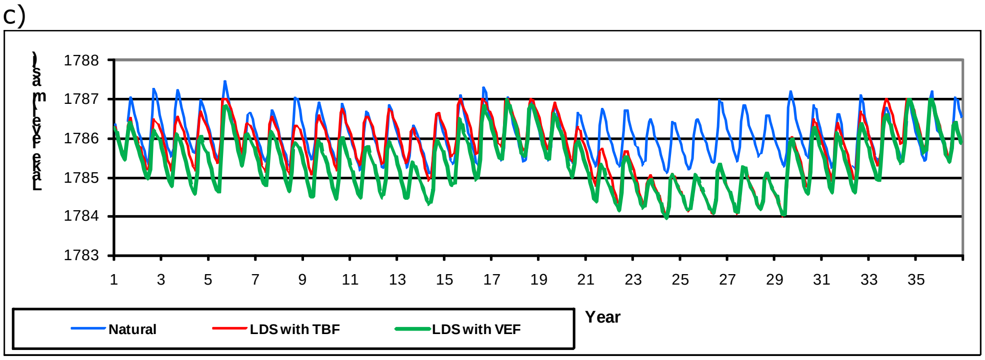
a)



b)



c)



d)

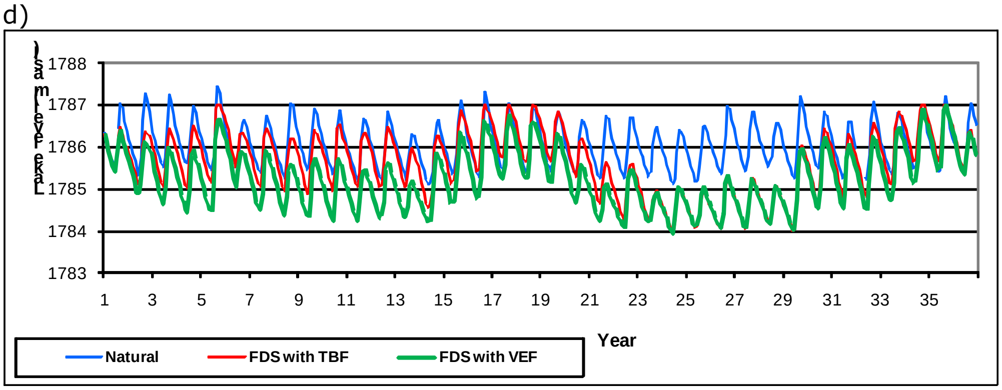


Figure 6.3. Comparison of simulated and natural (observed) lake levels over 36 years with, for each scenario, with the minimum maintenance flow (TBF) and the variable environmental flows (VEF). Scenarios are: a) baseline scenario (BS), b) ongoing development scenario (ODS), c) likely development scenario (LDS) and d) full development scenario (FDS).

Table 6.3. Summary of simulation results for each scenario with TBF and VEF

Scenario	TB F					VEF				
	Mean water levels (masl)	Mean lake area (km^2)	Mean power generated $GWhy^{-1}$	Mean irrigation water supplied Mm^3y^{-1}	% time that mean water level exceeds 1785 masl[a]	Mean water Levels (masl)	Mean lake area ($km^{2)}$	Mean power generated $GWhy^{-1}$	Mean irrigation water supplied Mm^3y^{-1}	% time mean water level exceeds 1785 masl
Natural	1786.1	3080	16*	0	100	1786.1	3080	16[b]	0	100
BS	1785.9	3070	445	0	88	1785.6	3045	333	0	75
ODS	1786.0	3077	2247	55	90	1785.9	3067	2225	54	89
LDS	1785.7	3057	2207	548	81	1785.4	3034	2178	537	66
FDS	1785.6	3049	2198.	677	78	1785.2	3023	2134	644	60

[a]1785 masl is the minimum level required for shipping
[b]hydropower produced by Tis Abay I power station by diverting unregulated flow

As would be expected, the greatest impact of the water resource development occurs during dry cycles, in particular years 8-14 and most significantly from years 20-28 of the simulation. During these periods, even without VEF releases, lake water levels are, depending on the development scenario, up to 0.82 m and 1.76 m lower than natural levels in the dry and wet season, respectively (Figure 6.3).

As development increases there are longer periods of time when mean monthly lake levels are below 1,785 masl (Table 6.3). Under natural conditions lake levels never dropped below this level. Under current conditions, they exceed it in 88.4% of months. In the Ongoing Development Scenario this will increase to 90.1%. The improvement occurs because the total demand of the Beles power station and Koga irrigation scheme (i.e., 3,047 Mm^3y^{-1}) is slightly less than current demand of the Tis Abay power stations (i.e., 3,469 Mm^3y^{-1}). However, when the additional irrigation schemes become operational, lake water levels will decline. In the Full Development Scenario, even without the VEF releases, water-levels exceed 1,785 masl just 78.0% of the time (Table 6.3). In some drier years (i.e. years 20 to 28) they hardly exceed this level in any month (Figure 6.3d).

In comparison to the TBF, the VEF requirements, because they necessitate more water flowing over the Falls, exacerbate the drop in lake water-levels in all scenarios. In the current situation the VEF would result in water levels being above 1,785 masl just 75.2% of the time (c.f. 88.4% with TBF). In the Full Development Scenario with VEF water level exceeds 1,785 masl just 59.7% of the time and the mean lake area is reduced from 3,080 km^2 to 3,023 km^2 (Table 6.3).

Table 6.4 presents the estimates of irrigation water that can be supplied at different levels of assurance in each of the scenarios. The results indicate that, as would be expected, as the level of water resource development increases (i.e., there are more dams built) the amount of water that can be supplied for irrigation at low assurance levels increases. The results also indicate that, again as would be expected, less water can be delivered at higher levels of assurance. This simply means that in years of lower rainfall and hence lower flow in the rivers, less water is available for irrigation. The results show that in years of very severe drought (e.g. approximately once in a 100 years) almost no water would be available for irrigation. Between the LDS and FDS, the increase in irrigated area results in a decrease in the amount of water that can be supplied at high levels of assurance. The results also show the degree to which, in all scenarios, implementation of the VEF reduces water availability for irrigation (i.e. from 1% to 68%). The VEF has a greater impact both at higher levels of assurance and higher levels of development.

Table 6.4. Comparison of scenarios: irrigation water that can be supplied at different levels of assurance (Mm^3y^{-1})

Assurance	Baseline[a]		ODS[b]		LDS[c]		FDS[d]	
level (%)	TBF	VEF	TBF	VEF	TBF	VEF	TBF	VEF
50	-	-	59	58	561	540	687	645
80	-	-	54	52	475	440	575	510
90	-	-	47	44	397	353	471	391
96	-	-	34	29	272	217	296	208
98	-	-	20	14	159	96	147	47
99	-	-	1	-	26	-	-	-

[a]Baseline = current situation; [b]ODS = Ongoing Development Scenario; [c] LDS = Likely Development Scenario; [d]FDS = Full Development Scenario

Table 6.5 presents the estimates of electricity that can be generated with different levels of assurance in each of the scenarios. These confirm that far more electricity is generated through implementation of the Tana Beles transfer than is currently produced from the Tis Abay power stations. The results show that in the Ongoing Development Scenario with the TBF, 1,903 $GWhy^{-1}$ can be generated with 99% assurance (i.e., less would be generated on average only once every 100 years). This compares to a firm energy estimate of 1,866 $GWhy^{-1}$ (Salini and Mid-day, 2006).

Table 6.5 shows that as irrigation in the Lake Tana basin increases, even though electricity generation is given the higher priority, the reliability of generation declines. Thus, in the Likely Development Scenario and the Full Development Scenario, electricity generation at the 99% assurance level decreases to 1,748 $GWhy^{-1}$ and 1,698 $GWhy^{-1}$ respectively. This is the consequence of reduced inflows to Lake Tana as a result of the increased irrigation. The results also show the degree to which, in all scenarios, implementation of the VEF further reduces the reliability of electricity generation. As with irrigation, the VEF has a greater impact on electricity generation both at higher levels of assurance and at greater levels of development.

Table 6.5. Comparison of scenarios: electricity that can be generated at different levels of assurance ($GWhy^{-1}$)

Assurance	Baseline		ODS		LDS		FDS	
level (%)	TBF	VEF	TBF	VEF	TBF	VEF	TBF	VEF
50	439	392	2,154	2,138	2,088	2,043	2,108	2,111
80	426	340	2,089	2,040	1,996	1,954	2,009	1,992
90	417	299	2,045	1,967	1,937	1,896	1,938	1,904
96	404	239	1,989	1,869	1,861	1,824	1,845	1,784
98	394	189	1,946	1,791	1,805	1,771	1,773	1,687
99	384	135	1,903	1,709	1,748	1,718	1,698	1,659

[a]Baseline = current situation; [b]ODS = Ongoing Development Scenario; [c] LDS = Likely Development Scenario; [d]FDS = Full Development Scenario

6.5 Discussion

The analyses conducted in this study quantify some of the possible impacts arising from future development of the water resources in the catchment. In the past, the water level of the lake was affected primarily by variation in rainfall (Kebede et al. 2006). The simulation results indicate that now, and increasingly in the future, anthropogenic activities will be the major control.

If the full development scenario in the Lake Tana catchment is implemented, approximately 3,600 Mm^3y^{-1} of water will be diverted for hydropower and irrigation schemes. As a result the mean annual water level will be lowered by 0.44 m and there will be prolonged periods, of several years, during which water levels will be much lower than they would be naturally. Furthermore, the average surface area of the lake will decrease by 30 km^2 (i.e. 1%). In some years it will be reduced by as much as 81 km^2 (i.e. 2.6%) during the dry season. This is likely to have significant impacts on the ecology of the lake, particularly in the littoral zone and in the wetlands around the shore.

The experience of 2003, when farmers extended crop production onto the lake bed indicates that lower water levels will almost certainly result in people moving both cultivation and grazing onto the dried lake bed. This would exacerbate adverse impacts on near-shore vegetation and could increase sedimentation in the lake. Moreover, during periods of several years of drawdown (as occurs during dry years 20-28 in the simulation) it is possible that people would move their homes onto the waterless lake bed, maybe to be closer to cultivated fields. In such a situation rapid rises in lake levels could be disastrous, threatening both livelihoods and houses. To avoid this it will be necessary to educate local populations about lake level changes.

Lower water-levels, particularly in the dry season, will have a negative impact on navigation. Since the livelihoods of many people depend on shipping, strategies need to be developed to mitigate these impacts. These could include modification of ports as well as the ships themselves to enable them to operate at lower water-levels.

The results show that as future irrigation increases, even though hydropower is given a higher priority, assured supplies for electricity generation will reduce. Although decisions concerning water allocation should not be guided by economic concerns alone, economic valuation can help to guide allocations by providing a common point of reference and highlighting trade-offs between competing needs (Turner et al., 2004). Consequently, it would be extremely beneficial for a future study to undertake a detailed economic analysis of the economic implications of increased irrigation versus the reduced reliability of electricity generation. For completeness such an assessment should also include planned irrigation schemes in the Beles catchment.

The results indicate that the allowance for VEF over the Tis Issat Falls reduces the availability of water for both hydropower and irrigation and causes increased drawdown of the lake. In the Full Development Scenario the VEF reduces the average lake levels by an additional 0.37 m and the average surface area of the lake by an additional 26 km^2 (i.e. 2,600 ha). This is over and above the reductions resulting from the TBF and will certainly exacerbate the adverse environmental and social impacts arising from drawdown of the lake. Therefore, a potential trade-off exists between the lake ecosystem and the ecosystem of the upper Abay River and the Falls. Since the livelihoods and well being of many people are directly dependent on the ecological character of both ecosystems, careful consideration needs to be given to determining how the water is best utilized. This requires much more detailed analyses of both the environmental and social consequences of water allocation patterns and very careful assessment of the implications for the livelihoods of the poor.

In this study no consideration was given to the possible impacts of climate change. Currently there is great uncertainty about the likely impacts of climate change in the Abay basin and Ethiopia generally. Results from Global Circulation Models (GCMs) are contradictory; some show increases in rainfall whilst others show decreases. A recent study of 17 GCMs indicated precipitation changes between -15% and +14% which, compounded by the high climatic sensitivity of the basin, translated into changes in annual flow of the Abay at the Sudan border of between -60% and +45% (Elshamy et al., 2008). Kim et al. (2008) found a generally increasing trend in both precipitation and runoff in the northern part of the basin. Other studies have found a decline in the runoff into Lake Tana (Shaka, 2008). To date no studies have been conducted into the possible changes in water demand arising from changes in temperature and rainfall in the Lake Tana catchment (e.g. for irrigation).

The water resources of the Lake Tana catchment are highly vulnerable to changes in rainfall and hence runoff (Kebede et al. 2006). The lack of certainty in rainfall and runoff trends greatly complicates water resource planning and management in what is already an uncertain environment. Climate change means that stationarity (i.e. the idea that flows fluctuate within an unchanging envelope of variability) can no longer be assumed and necessitates that all future water resource development is adaptable. Further research is needed to improve quantitative understanding of the climate change impacts on water resources and to fulfil the pragmatic information needs of water managers and decision-makers.

6.6 Conclusion

Currently the water resources of the Lake Tana catchment are largely unexploited and there remains potential for socio-economic development based on increased utilization of water. However, great care is needed to ensure that such development is sustainable and does not adversely impact those communities that depend on the natural resources of the lake and the rivers that feed into it. The predicted drop in average water levels of 0.44 m, and much more in prolonged dry periods, would have significant adverse ecological and social consequences. It is important that decision-makers take into account the potential costs as well as the benefits of development.

Further details of this component of the project are presented in Alemayehu (2008), Alemayehu et al. (2009) and McCartney et al. (in press).

OUTCOMES AND IMPACTS

The anticipated eventual impact of this project was improved water management in river basins that contain large dams, resulting in better livelihood outcomes through increased food security and improved or conserved environmental security. The intended ultimate beneficiaries were both people with reservoir-dependent livelihoods and people with downstream river-dependent livelihoods. This was to be brought about through a more equitable distribution of the benefits derived from large dams.

This section of the report focuses on the impact that the project has actually had. In common with all CPWF projects a participatory impact pathway approach was adopted. The primary objective of this was to maximize the impact of the project by purposefully designing a strategy for uptake of research results, rather than leaving it to chance.

Delays in holding the Nile Basin Impact Pathways workshop meant that this approach was not officially implemented until May 2008 (i.e. towards the end of the project). Prior to this the project was guided primarily by the logframe developed for the project proposal. This outlined measurable indicators of success and means of verification, but did not specify a strategy by which these would be achieved. Rather the approach adopted was broadly to disseminate research information as widely as possible, though with some targeting of institutions that were perceived to be influential both within the region and more widely (e.g., the Nile Basin Initiative and the UNEP Dams Development Project).

From the start of the project the primary output was intended to be guidelines on the use of DSSs for dam planning and operation. These were meant to inform policy-makers, water resource managers, and other interested stakeholders, about the contribution that Decision Support Systems (DSSs) can make to the planning and operation of large dams in Africa, with a focus on the need for more rigorously addressing the environmental and social issues associated with large dams.

The proforma below indicates the main impact pathways developed at the impacts pathway workshop. It was through these pathways that the project was intended to have impact.

7. Proforma

Summary Description of the Project's <u>Main</u> Impact Pathways

Actor or actors who have changed at least partly due to project activities	What is their change in practice? I.e., what are they now doing differently?	What are the changes in knowledge, attitude and skills that helped bring this change about?	What were the project strategies that contributed to the change? What research outputs were involved (if any)?	Please quantify the change(s) as far as possible
Researchers	Inter-institutional collaboration established. Professionals from different disciplines (e.g.	Increased knowledge of the environmental impacts of dams, the implications for communities	Established a research strategy and facilitated communication between researchers	Links established between Addis Ababa University and Bahar Dar University with researchers from advanced research intuitions and IWMI.

	engineering, public health, environmental scientists and social scientists) have come together and formed a team and shared knowledge in relation to dam planning and operation.	and how to incorporate these issues in dam planning and operation		International workshop organized in January 2006 that brought researchers (and others) from all around the world to Ethiopia
Graduate Researchers	Increased institutional capacity which in the future should influence institutional practices – making them more sensitive to environmental and social impacts of dams and how to incorporate these issues in dam planning and operation.	Increased knowledge of the environmental impacts of dams, the implications for communities and how to incorporate these issues in dam planning and operation	Support to graduate researchers – resources and supervision. Hopefully in future these students will be embedded within relevant institutions (i.e. government ministries and dam operators etc.)	7 Ethiopian graduate students undertook MSc research as a contribution to this project. All but one of these students remain in Ethiopia, working for government, universities and consultants. 3 non-Ethiopian students (2 from the USA and 1 from Uganda)
Policy makers	Create policy environment and legal instruments that enhance dam planning and operation	Full awareness of environmental and social impacts of dams. Recognition of environmental and social impacts of dams and move away from considering only the traditional economic benefits. Increased institutional capacity to regulate dam operators.	Policy briefs (under preparation) Policy influencing workshop. Presentations made at key international fora. Presentations made at key national fora	Key findings from the project have been presented at international fora including those organized by the NBI and the UNEP Dams Development Project. Key findings from the study have been presented at national fora, including those on water resources in Ethiopia and the Nile Basin and also health and climate workshops. Policy influencing workshop attended by officials from key ministries as well as the Nile Basin Initiative

				and Eastern Nile Technical Resource Office (September 2009).
Dam proponents and operators	Improved dam planning and operation that takes better account of environmental and social issues	Increased awareness of issues and there importance as well as the advantages to be gained if they are adequately planned for throughout the project cycle.	Article printed in practitioner journals. Development of practitioner guidelines. Policy influencing workshop. Input to industry guidelines and standards	Article printed in hydropower practitioner magazine, HRW Practitioner guidelines produced – currently under review. Policy influencing workshop attended by dam operators from Ethiopia, Uganda, Sudan and Egypt (September 2009) Feedback provided to International Hydropower Associations, Hydropower Sustainability protocol

Of the changes listed above, which have the greatest potential to be adopted and have impact? What might the potential be on the ultimate beneficiaries?

At this point it is not really possible to say which of the pathways above has the greatest potential to be adopted. All are required to maximize project impact but the time lines over which they will influence change vary. For example, the impact of the capacity building of students, which ultimately may have significant consequences, may not be felt for a number of years. In contrast if we have managed to influence current policy-makers or dam operators (which we may have, though it will always be difficult to attribute this to a single project) then impact may be more rapid. There is no doubt that in the Nile Basin the project has increased awareness of the issues of dams environmental and social impacts and has hopefully provided "food for thought" for a number of currently influential government officials and dam proponents.

At the end of the day it is changes in policy and the way that they are implemented (i.e. the last two pathways) that will bring about the desired impacts for the intended beneficiaries of the project. This project has shown very clearly that even where current policies are reasonable (e.g. in relation to EIAs), if they are not ascribed sufficient priority or if the capacity to implement them is lacking then they fail to bring about desired results. Thus policy modification is a necessary but not sufficient factor in influencing impact.

What still needs to be done to achieve this potential? Are measures in place (e.g., a new project, on-going commitments) to achieve this potential? Please describe what will happen when the project ends.

To ensure the desired impact of the project a lot of work remains to be done. Although this project has undeniably increased awareness, further work is needed to change the currently widely accepted premise that detailed consideration of environmental and social issues in dam planning and operation is a "luxury" that the developing countries of the Nile Basin cannot afford. Many people continue to believe that the negative impacts of development are a price that has to be paid if the countries are to develop and only when they are wealthy enough can these issues be addressed.

Specifically for this project there is need to write the policy briefs that were proposed. This is currently being done and two IWMI water policy briefs will be produced in the near future. Engagement with policy makers and dam proponents will continue in future though in a more *ad-hoc* manner than has occurred over the life of the project.

Work in the Nile basin is continuing with relevant projects being:

- A research project on water storage for climate change adaptation in sub-Saharan Africa. This project which is evaluating the role of all water storage types (i.e. not just large dams) is led by IWMI and funded by GTZ.

- Development of the Decision Support System for the Nile Basin (NB-DSS). This project is being undertaken by a team in the NBI over the next three years. The aim is to develop a DSS to assist with water resource planning throughout the Nile Basin. Findings from the current project have been communicated to the team developing the NB-DSS.

It is also hoped that many of the findings from this project will be relevant to the CPWF phase II projects in the Mekong which are focused on reducing poverty and fostering development through management of water for multiple uses in large and small reservoirs. The draft guidelines have been sent to the project leader and others involved in the Mekong project 1 – optimizing reservoir management for livelihoods.

Each row of the table above is an impact pathway describing how the project contributed to outcomes in a particular actor or actors.
Which of these impact pathways were unexpected (compared to expectations at the beginning of the project?)

As noted above, the impact pathways were not articulated at the beginning of the project. However, perhaps the most surprising aspect of the project was the limited understanding of some issues by some key stakeholders very closely related to dam operation. For example, some had never heard of environmental flows despite the fact that it has been a key area of research, and in other countries a key aspect element of dam operation, for many years.

Why were they unexpected? How was the project able to take advantage of them?

This finding increased our appreciation of the need for even basic awareness raising and better targeting of messages within the guidelines developed. It will also help us write the policy briefs planned for the near future.

What would you do differently next time to better achieve outcomes (i.e. changes in stakeholder knowledge, attitudes, skills and practice)?

The following are simple recommendations to better achieve project outcomes:

- Initiate impact pathways thinking and approach from the start of the project. From the experience of this project, it does not work particularly well to add this during the project.
- Ensure sufficient time is devoted by key researchers to enable them to work on the impact pathways and uptake by partners. Get this recognized as a key part of their job and not, as currently, of lower importance in terms of their personal

performance, than producing peer reviewed publications.
- Ensure projects collaborate with partners who have a track record of facilitating uptake.

8. International Public Goods

The project produced many insights into the planning and operation of large dams in the Nile. It validated the hypothesis that environmental and social issues are worthy of more consideration and must be given greater emphasis in future dam planning and operation. Furthermore, it confirmed that, contemporary DSSs can usefully assist in many aspects of decision-making processes, throughout the life-cycle of a large dam. Many of the project findings are applicable throughout Africa and indeed globally. Key public goods produced include:

- The guidelines on the use of DSSs in relation to key aspects of dam planning and operation (McCartney and King, in press).
- 13 peer reviewed papers published in international journals and two peer reviewed research reports (section 11 and Annex 1).
- 30 non peer reviewed papers published in various places including conference proceedings, workshop proceedings and newsletters (section 11)
- 8 post graduate student theses, with hopefully one more to come (see section 11)

8.1 Tools and methodology

The guidelines (the primary output from the project) provide an overview of key issues and describe how the benefits of dams can be enhanced, and the adverse impacts avoided or mitigated, by applying better decision-making processes, specifically through the application of Decision Support Systems (DSSs). The guidelines illustrate the importance of environmental and social issues in dam planning and operation. Key (generic) messages from the guidelines are summarized in Table 8.1

Table 8.1. Key messages expanded upon in the guidelines

- Large dam construction in Africa is set to increase in the near future. The new dams have the potential to bring significant social and economic benefits. To maximize these benefits, mistakes associated with dam building in the past must be avoided. This requires better dam planning and management.
- River ecosystems are complex interlinked systems supporting immense biodiversity all of which is directly or indirectly maintained by constantly changing river flow, including floods. If the natural flow regime is disturbed by a dam much of the biodiversity and many of the ecosystem services are placed at risk.
- River ecosystems are valuable to people. This value should not be under-estimated. Dams are constructed to bring social and economic benefits, but they are also associated with social costs. It is essential that decision-makers take into account not only the benefits but also the potential costs of dams and either avoid or mitigate them. Balancing the needs of different sectors of society is a key challenge facing dam developers.
- Both the nature of decisions and those making the decisions change at different stages in the planning cycle of a large dam. The information required at each stage varies but throughout the ecological and social implications should be attributed equal weight to the engineering and economic aspects. DSSs can assist decision-making at all stages of the project cycle.
- Faced with growing concerns over the sustainability of water use, many

African countries are focusing increasingly on the development of integrated basin-wide approaches to water management. In this endeavor DSSs are useful tools to assist with the planning and operation of large dams. However, there are a number of constraints to the use of DSSs in Africa. These need to be overcome to ensure the advantages to be obtained from DSSs are fully realized.

- Throughout Africa there is an urgent need to enhance the benefits of dams whilst minimizing the negative impacts. Broadly this requires better decision-making processes that: i) strengthen stakeholder involvement, ii) improve EIAs, iii) improve consideration of downstream environmental and social impacts, iv) take better account of possible public health impacts, v) improve options assessment, vi) improve mechanisms for benefit sharing, and vii) improve water resources management in transboundary basins.

8.2 Key insights

Of the knowledge gained in this study, perhaps the most beneficial in the long-term will be:

- the insights gained from the research on dam impacts on malaria. Although the potential health impacts of large dams are broadly understood, there is relatively little systematic research into these impacts and almost no quantitative information on the impacts in sub-Saharan Africa. This project was one of only a handful that has combined entomological and epidemiological studies to investigate this and to our knowledge is the only one in Africa to investigate the potential for using dam operation as a malaria mitigation measure (see objective 4).
- the insights gained on the potential impacts of future water resource development in the Lake Tana basin. The potential for very serious environmental and social impacts is great and must be given much greater consideration in future planning (see objective 6).
- the insights gained into stakeholder perceptions of decision-making processes in relation to both dam planning and operation. To date very few studies have investigated public perceptions of decision-making processes and the long-term impacts of dams on local populations. This component of the project highlighted the fact that dams completely alter the social landscape of the region in which they are constructed and illustrated the imperative for incorporating the public in decision-making processes (see objective 1).
- the insights gained into EIA follow-up. This highlighted the need to treat EIAs seriously and to put in place measures to ensure that EIA recommendations are implemented. Without such measures no matter how well the actual EIA its effectiveness will be at best limited (see objective 3).

9 Partnership Achievements

The partnership developed for this project was reasonably compact – there were just 3 key partners - partly in order to reduce the transaction costs associated with large partnerships. Despite the fact that it was small, it was effective as indicated by the research outputs and the large body of knowledge generated. The PIs involved in the project brought to it a wide range of complementary skills and techniques essential for a multi-disciplinary approach.

Staff from the University of Addis Ababa brought to the project detailed experience and expertise of water resource planning as well as in-depth knowledge of stakeholders in Ethiopia. They also facilitated access to students and enabled their participation in key aspects of the project. They also provided great assistance with data collection and keeping abreast of developments and planning in the Nile basin. There is also little doubt that the Ministry of Water Resources, Nile Basin Initiative (NBI) and other national institutions have been more receptive to project findings because they are seen to have been partially produced and are fully endorsed by the University professors involved.

Jackie King from Southern Waters brought to the project considerable international experience and contemporary thinking related to large dam planning and operation. Her insights and suggestions for research directions were invaluable. She greatly assisted with advise on appropriate techniques for the integration of biodiversity and ecological issues into DSSs; advise on the contribution of DSSs to design of environmental flow assessments and the link to stakeholder concerns; advise on integrated flow assessments.

10 Recommendations

Key recommendations from the project have been made in the papers and reports published. Many of these are recommendations specific to the case studies. However, on the basis of knowledge gained a number of generic recommendations concerning the use of DSSs for dam planning and operation in Africa have been made and are summarized below (McCartney and King, submitted):

- *Social issues:* The concerns relating to large dams are complex, encompassing many interlinked social, economic and ecological dimensions. The social complexity of such schemes requires that social components should be given as much, or even greater, consideration than technical aspects in project planning. To minimize unwarranted social stress, requires that all stakeholders understand the scheme and participate in decision-making from an early stage. DSSs can contribute to this process by identifying the social implications of biophysical changes arising from dam construction and operation. To empower stakeholders in negotiating processes DSSs need to provide and present information that is understandable to a range of stakeholders, including non-technical people.

- *Implementation of EIA:* Successful implementation of EIA recommendations requires that both policies and institutions are in place to enable adequate follow-up. It also requires that project managers have the tools necessary to facilitate the effective monitoring of impacts and to predict the potential consequences of changes arising from dam construction and operation. DSSs can help with determining possible differences in outcomes and impacts arising from different scenarios of development or different modes of operation of a dam. DSSs can also help improve follow-up mechanisms by, amongst other things, providing dam operators with tools to assist in the archiving, analyses and interpretation of data collected in monitoring networks established through EIAs. The intention is to provide insights into how the system (including social components) are being impacted by a dam and to facilitate informed decision-making to enable adjustments to be made in the way it is operated.

- *Environmental Flows:* Environmental flows are essential for the sustainable and equitable development of aquatic resources. The broad impacts of flow regime changes caused by dams are now reasonably well understood. However, all dams are unique and there is often great uncertainty of specific impacts and in particular the likely socio-economic implications of change. DSSs are increasingly being combined with expert judgment to gain insights into flow-ecosystem links and in turn the links to livelihoods. The countries of sub-Saharan Africa would benefit significantly from programs to build capacity in environmental flow assessment. As a starting point, these should be developed using the expert opinion of national ecologists, hydrologist, social scientists and others who have detailed knowledge and experience of the region's rivers, with guidance from experts in the process of environmental flow assessment. Such programs should include research to better understand flow-ecology-livelihood links as well as how to proceed with limited knowledge and improve relevant DSSs. Even if the initial results are uncertain, attempting environmental flow assessment, utilizing teams of appropriately guided experts, would facilitate holistic approaches and assist interactions between different disciplines. This would be a useful first step in the development of national and regional expertise in environmental flow assessment.

- *Health impacts:* In Africa there are strong links between disease and the construction of infrastructure, including dams. However, the health impacts arising from the construction and operation of dams are often poorly understood and often overlooked during dam planning and operation. DSSs can contribute significantly to both improved understanding of the complex links between disease vectors and reservoirs and also better management of likely health impacts. Many models have been developed that simulate the mechanisms underlying disease vector dynamics and their relations to the environment. Although much research still needs to be undertaken, these models enable a better understanding of the mechanisms underlying disease transmission both generally and also in specific geographic environments. As such they provide a starting point for predicting the likely impacts prior to dam construction and the impacts that may arise from specific interventions to reduce transmission. By quantifying the likely health impacts, DSSs can contribute to Health Impact Assessments (HIAs) which provide a systematic approach for screening, assessing, appraising and formulating management plans to address key public health issues associated with large dams. However, while most African countries have a framework for EIAs few possess adequate capacity for HIAs. A policy shift is required to build capacity and ensure that institutions promote integrated Environmental Health Impact Assessments rather than simple EIA.

- *Options assessment*: Comprehensive options assessment of dams and their alternatives is critical for sustainable development. In any given situation, development needs should be matched to the most appropriate development options. Hence, before a dam is built a "needs assessment" should be conducted and a dam (or dams) must be identified as the most feasible/beneficial option. Clearly a comprehensive assessment requires a detailed evaluation of the implications (both positive and negative) of different options for fulfilling needs. DSSs can contribute to options assessment both by assisting in the identification of needs (across a range of scales) and by providing information on the likely consequences of a range of approaches to satisfy the identified needs. At the national level DSSs can also provide information to assist with the establishment of goals, policies and procedures that facilitate proper options assessment. Where dams are being considered DSSs can contribute to the options assessment by investigating their impact both individually and cumulatively within a catchment

- *Benefit sharing:* Too often, in project planning and implementation, the national interest has been the primary consideration and local concerns have been neglected. Ensuring equitable outcomes from development requires that measures are developed to sufficiently off-set any negative impacts. To design adequate benefit sharing mechanisms understanding of local conditions and good data are essential. In the past even where social baselines have been established data on living standards linked to livelihoods are often missing. As a result, it is impossible to determine whether living standards have been restored or improved in the great majority of projects. This is a serious omission which hinders the implementation of remedial measures and ultimately undermines evaluations of the extent to which projects are a success. Post project evaluation of the success/failure of compensation and benefit sharing mechanisms are very rare. However, past experience shows that in cases where compensation packages were negotiated with project affected communities the process has resulted in better outcomes. Even when, for whatever reason, the negotiated form of compensation proves not to be the most appropriate or effective option, project affected people tend to feel more satisfied, as a result of the negotiation process.

- *Transboundary waters:* Africa is a continent with a large number of rivers that cross international borders, so called "transboundary" rivers. Decisions pertaining to large dam planning and operation made by individual states within transboundary basins are rarely equitable nor, when viewed from the perspective of the entire basin, as effective or efficient as they could be. The challenges in developing DSSs that will be accepted by all the riparian states are manifold. However, when they can be implemented within an appropriate institutional framework, they have an important role to play in building confidence, enhancing cooperation and maximizing the multiple benefits that can be generated within a basin.

11 Publications

11.1 Peer reviewed

Brown, C; Watson, P. 2007. Decision support systems for environmental flows: lessons from southern Africa. *International Journal of River Basin Management* 5(3) 169-178*.

Dlamini, E.M. 2007. Decision support systems for managing the water resources of the Komati River Basin. *International Journal of River Basin Management* 5(3) 179-188*.

Egre, D.; Roquet, V.; Durocher, C. 2007. Monetary benefit sharing from dams: a few examples of financial partnerships with indigenous communities in Quebec (Canada). *International Journal of River Basin Management* 5(3) 235-244*.

Greef, L. 2007. South African multi-stakholder initiative in formulating policy on dams and development. *International Journal of River Basin Management* 5(3) 189-198*.

Kibret, S.; McCartney, M.P.; Lautze, J.; Jayasinghe, G. 2009. Malaria transmission in the vicinity of impounded water: evidence from the Koka reservoir, Ethiopia. Colombo, Sri Lanka: International Water Management Institute (IWMI Research Report 132) 47 pp.

King, J.; M^c^Cartney, M.P. 2007. Dams, ecosystems and livelihoods. *International Journal of River Basin Management* 5(3) 167-168*.

Lautze, J.; Kirshen, P. 2007. Dams, health and livelihoods in Africa: lessons from the Senegal, suggestions for Africa *International Journal of River Basin Management* 5(3) 199-206*.

Lautze, J.; McCartney, M.P.; Kirshen, P.; Olana, D.; Jayasinghe, G.; Spielman, A. 2007. Effect of a large dam on malaria risk: the Koka Reservoir in Ethiopia *Tropical Medicine and International Health* 12(7) 1-10.

Lovich, J.; Melis, T.S., 2007. The state of the Colorado River ecosystem in the Grand Canyon: lessons from 10 years of adaptive ecosystem management. *International Journal of River Basin Management* 5(3) 207-221*.

McCartney, M.P.; Sally, H. 2007. Managing the environmental impact of large dams. In: Prabha, Shastri Ranade (Ed) Rivers, Dams and Development: Issues and Dilemmas, 2007, Icfai University Press, India 88-104.

McCartney, M.P. 2009. Living with dams: managing the environmental impacts. *Water Policy* 11(1) 121-139.

McCartney, M.P., Shiferaw, A., Seleshi, Y. 2009a. Estimating environmental flow requirements downstream of the Chara Chara weir on the Blue Nile River. *Hydrological Processes* (DOI 10.1002/hyp.7254) 8pp.

McCartney, M.P.; Alemayehu, T.; Shiferaw, A.; Awulachew, S.B. (in press) Evaluation of current and future water resource development in the Lake Tana Basin, Ethiopia. Colombo, Sri Lanka: International Water Management Institute (IWMI Research Report) (forthcoming).

Meijer, K.S.; Hajiamiri, S. 2007. Quantifying well-being values of environmental flows for equitable decision-making: a case study of the Hamoun wetlands in Iran. *International Journal of River Basin Management* 5(3) 223-233*.

Wold, B.; Flatby, R.; Konow, T.; Lokke, K. 2007. Licensing for dam construction and operation – practical decision support developed and improved over 100 years. *International Journal of River Basin Management* 5(3) 245-250*.

11.2 Non-peer reviewed

Abebe, W.B.; McCartney, M.P.; Doueven; W.J.A.M.; Leentvaar, J. 2008. EIA follow-up in the Koga Irrigation project, Ethiopia. Proceedings of the 2nd International Forum on Water and Food (Addis Ababa 9-14 November, 2008) Vol II 52-55.

Alemayehu, T., McCartney, M.P.**,** Kebede, S. 2009. Modelling to evaluate the water resource implications of planned infrastructure development in the Lake Tana sub-basin, Ethiopia. Proceedings of Conference: Applying WEAP as a Decision Support System (DSS) for IWRM, Damascus, Syria 25-27 May 2009.

Chegwin, M.; Oud, E. 2006. Simple expert systems for guiding decision-making on multi-purpose dam releases. Proceedings of the International Working Conference: Enhancing equitable livelihood benefits of dams using decision support systems 23-26 January 2006, Adama/Nazareth, Ethiopia (CD only)+.

Fink, M. 2006. Integrating the World Commission on Dams recommendations in large dam planning processes: the case of Bui, Ghana. Proceedings of the International Working Conference: Enhancing equitable livelihood benefits of dams using decision support systems 23-26 January 2006, Adama/Nazareth, Ethiopia (CD only)+.

Finlayson, C.M.; McCartney, M.P. 2007. The contradictions of river regulation. *Aqua Australis* Newsletter of the Australian Hydrology Society.

Gaur, A.; Biggs, T.; Gumma, M.K.; Turral, H.; Parthasaradhi, G. 2006. Implications of spatial distribution of canal flows from a reservoir on land use. Proceedings of the International Working Conference: Enhancing equitable livelihood benefits of dams using decision support systems 23-26 January 2006, Adama/Nazareth, Ethiopia (CD only)+.

Georgakakos, A.P. 2006. Decision support systems for water resources management: sate of the science review and Nile Basin applications. Proceedings of the International Working Conference: Enhancing equitable livelihood benefits of dams using decision support systems 23-26 January 2006, Adama/Nazareth, Ethiopia (CD only)+.

Hathaway, T. 2006. Resolving unnecessary social and emvironmental costs of continuing flawed operations in Africa. Proceedings of the International Working Conference: Enhancing equitable livelihood benefits of dams using decision support systems 23-26 January 2006, Adama/Nazareth, Ethiopia (CD only)+.

Jethoo, A.S. 2006. Financial feasibility of irrigation projects with resettlement costs. Proceedings of the International Working Conference: Enhancing equitable livelihood benefits of dams using decision support systems 23-26 January 2006, Adama/Nazareth, Ethiopia (CD only)+.

Kibret, S.; McCartney, M.P.; Lautze, J. 2008. Mosquitoes and malaria in the vicinity of the Koka reservoir, Ethiopia. Proceedings of the 2nd International Forum on Water and Food (Addis Ababa 9-14 November, 2008) Vol I 34-37.

Khelifi, O. 2006. Decision support tool for water remediation technologies assessment and selection. Proceedings of the International Working Conference: Enhancing equitable livelihood benefits of dams using decision support systems 23-26 January 2006, Adama/Nazareth, Ethiopia (CD only)+.

Lautze, J., McCarney, M.P.; Olana, D. 2007. Malaria cases in relation to proximity to the Koka Reservoir. Water Figures Africa (Issue 1, May, 2007). IWMI Newsletter.

Lautze, J.; McCartney, M.P.; Kibret, S.; Griffiths, J. 2008. Dam operation and malaria transmission in Ethiopia. In: Proceedings of the World Environmental And Water Resources Congress, 2008, Ahuapua, Hawaii (doi 10.1061/40976(316)553)

McCartney, M.P.; Awulachew, S.; Seleshi, Y.; Prasad, K., King, J.; Tarekegn, D. 2005. Decision support systems for dam planning and operation in Africa. 2005. Decision support systems for dam planning and operation in Africa. Challenge Program for Water and Food: Project Leaders Meeting. Entebbe, Uganda 28th November – 01st December 2005.

McCartney, M.P.; Awulachew, S. 2006. Improving dam planning and operation in the Nile Basin through the use of decision support systems. In: *The role of the River Nile in Poverty Reduction and Economic Development in the Region*. Proceedings of the Nile Basin Development Forum (Addis Ababa, Ethiopia, 30 November – 02 December 2006) 309-324.

McCartney, M.P. 2007. Using Decision Support Systems to Improve the Planning of Large Dam Operations. Article in HRW magazine (March 2007).

McCartney, M.P. 2007. Decision support systems for dam planning and operation in Africa. Colombo, Sri Lanka: International Water Management Institute. 47 pp. (Working Paper 116).

McCartney, M.P.; Shiferaw, A.; Seleshi, Y. 2008. Estimating environmental flow requirements downstream of the Chara Chara weir on the Blue Nile River. In: Abtew, W. & Melesse, A.M. (eds) *Conference Proceedings: Hydrology and Ecology of the Nile River Basin Under Extreme Conditions* 16-19 June 2008, Addis Ababa, 57-75.

McCartney, M.P.; King, J. submitted. Use of decision support systems to improve large dam planning and operation in Africa. CPWF working paper (forthcoming).

Morrissey, J. 2006. Local livelihoods at risk: the construction and operation of Mphanda Nkuwa hydroelectric dam in Tete, Mozambique. Proceedings of the International Working Conference: Enhancing equitable livelihood benefits of dams using decision support systems 23-26 January 2006, Adama/Nazareth, Ethiopia (CD only)+.

Ndiritu, J.G. 2006. Combined simulation and optimization for reservoir system sizing and operation. Proceedings of the International Working Conference: Enhancing equitable livelihood benefits of dams using decision support systems 23-26 January 2006, Adama/Nazareth, Ethiopia (CD only)+.

Pant, D.; Samad, M. 2006. Stakeholder consultation and water governance: lessons from the Melamchi Water Transfer Project in Nepal. Proceedings of the International Working Conference: Enhancing equitable livelihood benefits of dams using decision support systems 23-26 January 2006, Adama/Nazareth, Ethiopia (CD only)+.

Petersson, E.; Ostrowski, M. 2006. Strengths and weakness of decision support systems in reservoir operation. Proceedings of the International Working Conference: Enhancing equitable livelihood benefits of dams using decision support systems 23-26 January 2006, Adama/Nazareth, Ethiopia (CD only)+.

Seleshi, Y. 2006. Comparison of existing Koka dam release rules with HEC-5, a dam DSS tool, release rules. Proceedings of the International Working Conference: Enhancing equitable livelihood benefits of dams using decision support systems 23-26 January 2006, Adama/Nazareth, Ethiopia (CD only)+.

Shiferaw, A.; McCartney, M.P. 2008. Investigating environmental flow requirements at the source of the Blue Nile River. Proceedings of the International Nile Basin Development Forum (Khartoum, 3-5 November, 2008) 14 pp.

Shiferaw, A.; McCartney, M.P.; Seleshi, Y.; Woldu Z. 2008. Major impacts of the Chara Chara weir and environmental implications. Proceedings of the 2nd International Forum on Water and Food (Addis Ababa 9-14 November, 2008) Vol II 75-78.

Smithers, A.C.; Butler, A.J.E.; Jewitt, G.P.W.; Clark, D.J.; Schulze, R.E. 2006. The development of a dam operating rule framework for the *ACRU* model to satisfy the requirements of the National Water Act in South Africa. Proceedings of the International Working Conference: Enhancing equitable livelihood benefits of dams using decision support systems 23-26 January 2006, Adama/Nazareth, Ethiopia (CD only)+.

Zaake, B.; McCartney, M.P. 2008. Evaluation of the water budgets of the Equatorial Lakes of the White Nile. International Nile Basin Development Forum (Khartoum, 3-5 November, 2008) 15 pp.

Zaake, B.; McCartney, M.P. 2008. Enhancing stakeholder participation in regulation studies of the Equatorial Lakes. Proceedings of the 2nd International Forum on Water and Food (Addis Ababa 9-14 November, 2008) Vol II 280-283.

11.3 Student theses

Abebe, W. 2007. EIA implementation and follow-up: a case study of the Koga irrigation and watershed management project, Ethiopia. MSc thesis. UNESCO-IHE, Netherlands.

Alemayehu, T. 2008. Application of the WEAP model to assess the water resource implications of planned development in the Lake Tana sub basin, Ethiopia. MSc. thesis. Addis Ababa University, Ethiopia.

Daniel, G. 2007. Determination of optimal reservoir operation rule curves for the Finchaa hydropower project. MSc. thesis. Addis Ababa University, Ethiopia.

Gebremeskel, Y. 2007. Intra-household preferences and willingness to pay for improved malaria treatment: a case study around Koka Dam. MSc. thesis. Addis Ababa University, Ethiopia.

Lautze, J. 2007. Incorporating malaria control into reservoir management: a case study from Ethiopia. PhD thesis. Tufts University, USA.

Mellese, B. 2008. The effects of water physical quality and water level changes on the occurrence of larvae of Anopheles mosquitoes around the Koka Dam, Ethiopia. MSc. thesis. Addis Ababa University, Ethiopia.

Reis, J. forthcoming. Integrating malaria controls into multi-purpose reservoir management: Koka Dam Reservoir, Ethiopia. MSc thesis. University of Virginia, USA.

Shiferaw, A. 2007*. Environmental flow assessment at the source of the Blue Nile River, Ethiopia*. MSc. thesis. Addis Ababa University, Ethiopia.

Tesfaye, A. 2008. The role of predators and competitors in controlling mosquito larvae abundance in the vicinity of the Koka Dam reservoir, Central Ethiopia. MSc. thesis. Addis Ababa University, Ethiopia.

Zaake, B. forthcoming. Use of decision support systems for improved planning and operation of large dams along the Victoria Nile. PhD thesis. University of Kwa Zulu Natal, South Africa.

Zaake, B. 2007a. Use of decision support systems for improved planning and operation of large dams along the Victoria Nile. Detailed PhD proposal submitted to the University of Kwa Zulu Natal, South Africa.

11.4 Project Reports

Gebre, A; Getachew, D.; McCartney, M.P. 2007a. Koka stakeholder survey. Project report for CPWF project 36: Improved planning of large dam operation: using decision support systems to optimize livelihood benefits, safeguard health and protect the environment. International Water Management Institute (IWMI).

Gebre, A.; Getachew, D.; McCartney, M.P. 2007b. Chara Chara stakeholder survey. Project report for CPWF project 36: Improved planning of large dam operation: using decision support systems to optimize livelihood benefits, safeguard health and protect the environment. International Water Management Institute (IWMI).

Hailu, D.; Seleshi, Y. 2005. Field survey report on current practices of dam operation in Ethiopia. Addis Ababa University.

McCartney, M.P. 2006. Report on the International Working Conference: Enhancing equitable livelihood benefits of dams using decision support systems. 23-26 January 2006 Adama/Nazareth, Ethiopia. International Water Management Institute (IWMI).

McCartney, M.P. 2008. Report on the Guidelines Writing Workshop. Living with dams: use of DSS to better manage environmental and social impacts in Africa. 02-04 April 2008, Bahar Dar, Ethiopia. International Water Management Institute (IWMI).

Zaake, B. 2007b. Report on the stakeholder meeting: enhancing applicability of innovative methodologies and tools to improve engagement and participation of stakeholders and decision-makers at every stage of the decision process in the management of dams along the Victoria Nile in Uganda. 19-20 July 2007, Entebbe, Uganda.

* Paper in special edition of the International Journal of River Basin Management (2007). These papers were written for *the International Working Conference: Enhancing equitable livelihood benefits of dams using decision support systems*, which was organized by this project 23-26 January 2006 in Adama/Nazareth, Ethiopia.

+ Paper presented at the International Working Conference: Enhancing equitable livelihood benefits of dams using decision support systems, which was organized by this project 23-26 January 2006 in Adama/Nazareth, Ethiopia.

BIBLIOGRAPHY

Acres; Shawel, 1995. Feasibility study of the Birr and Koga irrigation project, Koga catchments and irrigation studies, annexes Q-T.

African Development Bank (AfDB) 2003. Involuntary Resettlement Policy http://www.afdb.org/fileadmin/uploads/afdb/Documents/Policy-Documents/10000009-EN-BANK-GROUP-INVOLUNTARY-RESETTLEMENT-POLICY.PDF
(accessed September 2009)

African Development Bank (AfDB), 2001. Koga Irrigation and Watershed Management Project: Appraisal Report. (Available on http://www.afdb.org)

African Development Bank (AFDB), 2000. Summary Environmental Impact Assessment, Koga Irrigation and Watershed Management Project.

Allen, R.G.; Pereira, L.S.; Raes, D.; Smith, M. 1998. Crop evapotranspiration: guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper 56. Food and Agriculture Organization of the United Nations. Rome, Italy.

Ameneshewa, B.; Service, A. 1996. Resting habits of *Anopheles arabiensis* in the Awash River Valley of Ethiopia. *Annals of Tropical Medicine and Parasitology* 90: 515-521.

Arebo, S.G. (2005), *Improving Environmental Impact Assessment for Enhancing Sustainable Water Resources Developments in Ethiopia*, MSC thesis, UNESCO-IHE Institute of Water Education, Delft.

BCEOM, 1998. "Abbay river basin integrated development master plan, section II, volume V-water resources development, part 1- irrigation and drainage." Ministry of Water Resources, Addis Ababa, Ethiopia.

Bellier, C.; Howard, H.; Kennedy, R.; Donkin. 1997. Tis Abay II hydroelectric project, environmental impact assessment. Federal Democratic Republic of Ethiopia, Ministry of Water Resources, Addis Ababa, Ethiopia.

Carrara, G. C.; Petrarca, V.; Niang, M.; Coluzzi, M. 1990. *Anopheles pharoensis* and transmission of *Plasmodium falciparum* in the Senegal River delta. *Medical and Veterinarian Entomology* 4: 421–424.

Castelletti, A.; Soncini-Sessa, R.; Cellina, F.; Weber, E., 2004. The PIP procedure in the planning of lake Verbano, In: IFAC Workshop on Modelling and Control for Participatory Planning and Managing Water Systems, Venezia, Italy.

Central Statistics Authority (CSA) 2003. "Ethiopian agricultural sample enumeration, 2001/2002 results for Amhara region, statistical reports on area and production of crops, part II B". Central Statistics Agency, Addis Ababa, Ethiopia.

Draper, N.; Smith, H. 1998. Applied regression analysis, 3rd edition. New York: Wiley.

DWAF (Department of Water Affairs and Forestry), 1999. Resource Directed Measures for Protection of Water Resources Volume 8: *Classification System for Water Resources,* DWAF, Pretoria, South Africa.

Elshamy, M.E.; Seirstad, I.A.; Sorteberg, A. 2008. Impacts of climate change on Blue Nile flows using bias-corrected GCM scenarios. Hydrology and Earth System Sciences 5, 1407-1439.

Environmental Protection Land Administration and Use Authority (EPLAUA) (2004). "Water level reduction of Lake Tana and its environmental impacts". Bahir Dar, Ethiopia.

Environmental Protection Land Administration and Use Authority (EPLAUA). 2006. EPLAUA, Environmental protection study policy and control department; Koga Irrigation and Watershed Management Project field monitoring report, Bahir Dar, Ethiopia.

EPA, 2000. Environmental impact assessment guideline document; Federal democratic republic of Ethiopia.

Georgakakos, A.P., 2004. Decision support systems for integrated water resources management with an application to the Nile Basin, In: IFAC Workshop on Modelling and Control for Participatory Planning and Managing Water Systems. International Federation of Automotive Control, Venice.

Gustard, A.; Bullock, A.; Dixon, J.M. 1992. *Low flow estimation in the United Kingdom.* Institute of Hydrology Report 108. Institute of Hydrology, Wallingford.

Guyatt, H.; Ochola, S.; Snow. R. 2002. Too Poor to pay: charging for insecticide treated bednets in highland Kenya. *Tropical Medicine and International Health* 7: 846-850.

Hartley, N.; Wood, C. 2004. Public participation in environmental impact assessment-implementing the Aarhus Convention, *Environmental Impact Assessment Review,* 25, 319-340.

Hughes, D.A. 2001*. Providing Hydrological Information and Data Analysis Tools for the Determination of the Ecological In-stream Flow Requirements for South African Rivers. Journal of Hydrology*, 241 (1-2), 140-151

Hughes, D.A.; Hannart, P. 2003. A desktop model used to provide an initial estimate of the ecological in-stream flow requirements of rivers in South Africa*. Journal of Hydrology* 270 (3-4) 167-181.

International Commission on Large Dams (ICOLD) 2003. World Register of Dams, 2003. International Commission on Large Dams, Paris, France. 340 pp.

International Hydropower Association (IHA) 2009. World Atlas and Industry Guide. *The International Journal of Hydropower and Dams.* Aqua-Media International, Wallington UK.

Jagannathan, E.V.; Abebe, M. in press. The Tana Beles Growth Corridor: opportunities and challenges. In: Erkossa, T (ed) Improved water and land management in the Ethiopian highlands and its impact on downstream stakeholders dependent on the Blue Nile. Workshop Proceedings, Addis Ababa, 5-6 February, 2009.

Kashaigili, J.J.; McCartney, M.P.; Mahoo, H.F. 2007. Estimation of environmental flows in the Great Ruaha River Catchment, Tanzania. *Journal of Physics and Chemistry of the Earth* 32, 1007-1014.

Kebede, S.; Travi, Y.; Alemayehu, T.; Marc, V. 2006. “Water balance of Lake Tana and its sensitivity to fluctuations in rainfall, Blue Nile Basin, Ethiopia.” *Journal of Hydrology* 316, 233-247.

Keiser, J.; D. E. Castro; M. F. Maltese; R. Bos; M. Tanner; B. H. Singer; J. Utzinger. 2005. Effect of irrigation and large dams on the burden of malaria on a global and regional scale. *American Journal of Tropical Medicine and Hygiene* 72: 392-406.

Kibret, S. 2008. Entomological studies on the impact of a small-scale irrigation scheme on malaria transmission around Zeway, Central Ethiopia. MSc Thesis, Addis Ababa University.

Kim, U.; Kaluarachchi, J.J .; Smakhtin, V.U. 2008. Climate change impacts on hydrology and water resources of the upper Blue Nile Basin, Ethiopia. Colombo, Sri Lanka: International Water Management Institute 27p (IWMI Research Report 126).

King, J.; Louw, M.D. 1998. Instream flow assessments for regulated rives in South Africa using the Building Block Methodology. *Aquatic Ecosystem Health and Management*, 1, 109-124.

King, J; Tharme R.E.; de Villiers, M.S 2000 *Environmental flow assessment for rivers*; Manual for the building block methodology. Water research commission technology transfers report no TT/31/00 Pretoria South Africa

KIWMAP1, 2006. Koga Irrigation and Watershed Management Project; Progress of Watershed management project component implementation, Preliminary draft report.

Lengeler, C.; Snow, R. 1996. From efficacy to effectiveness: insecticide-treated bed nets in Africa. *Bulletin of the World Health Organization* 74: 325-332.

Marttunen, M.; Hamalainen, R.P., 1995. Decision Analysis Interviews in Environmental Impact Assessment. *Eur. J. Oper. Res*., 87: 551-563.

Marttunen, M.; Suomalainen, M., 2006. Participatory and multobjective development of water course regulation - creation of regulation alternatives from stakeholder's preferences. *Journal of Multi-Criteria Decision Analysis*, 13(1): 29-49.

Mott MacDonald, 1998. Lake Victoria regulation studies. WRAP Report No WRA03, Water Resources Assessment Project, Entebbe, Uganda.

Mott MacDonald, 2004a. Koga irrigation and watershed management project, Interim Report.

Mott MacDonald, 2004b. Koga irrigation and watershed management project, hydrology factual report.

Mott MacDonald, 2006a. Koga irrigation and watershed management project, Dam Design final report.

Mott MacDonald, 2006b. Koga Dam and Irrigation Project; Design final Report; Part 2: Irrigation and Drainage.

McCartney, M. P.; Boelee, E.; Cofie, O.; Mutero, C.M. 2007. Minimizing the negative environmental and health impacts of agriculture water resources development in sub-

Saharan Africa. Colombo, Sri Lanka: International Water Management Institute. IWMI Working paper 117. 41 pp.

Ministry of Finance and Economic Development (MoFED) 2006. A plan for accelerated and sustained development to end poverty (PASDEP), (2005/06-2009/10), volume I. Addis Ababa, Ethiopia.

Ministry of Health, 2005. *Malaria Profile*. Addis Ababa: Commercial Printing Press. Addis Ababa, Ethiopia.

Noble, B.; Storey, K. 2004. Towards increasing the utility of follow-up in Canadian EIA, Environmental Impact Assessment Review, 25, 163-180.

Pretty, J. 1995. Participatory learning for sustainable agriculture. *World Development* 23(8) 1247-1263.

Ribeiro, J.M.C.; Seulu, F.; Abose, T.; Kidane, G.; Teklehaimanot, A. 1996. Temporal and spatial distribution of mosquitoes in an Ethiopian village: Implication for malaria control strategies. *Bulletin of the World Health Organization* 74: 299-305.

Rogers, K.; Bestbier, R., 1997. Development of a protocol for the definition of the desired state of riverine systems in South Afica. Pretoria (S. Africa): South African Wetlands Conservation Programme, Dept. of Environmental affairs and Tourism.

Salini; Mid-day, 2006. "Environmental impact assessment for Beles multipurpose project." Ethiopian Electric and Power Corporation, Addis Ababa, Ethiopia.

Seddon, M.B. 2000. Molluscan biodiversity and the impact of large dams. IUCN, Gland, Switzerland

Shaka, A. 2008. Assessment of climate change impacts on the hydrology of the Gilgel Abbay catchment in the Lake Tana Basin, Ethiopia. MSc thesis, ITC, Netherlands 72 pp.

SMEC. 2008. "Hydrological Study of the Tana-Beles sub-basins, main report." Ministry of Water Resource, Addis Ababa, Ethiopia.

Soncini-Sessa, R.; Castelletti, A.; Weber, E., 2002. Participatory decision making in reservoir planning, In: Proceedings from iEMSs Integrated Assessment and Decision Support. Elservier, Lugano, Switzerland, pp. 34-44.

Staissny, M.L.J. 1996. An overview of freshwater biodiversity: with some lessons from African fishes. *Fisheries* 21, 7-13.

Stockholm Environment Institute (SEI) 2007. "WEAP: Water Evaluation and Planning system – user guide." Stockholm Environment Institute, Boston, USA.

Sutcliffe, J.V.; Parks, Y.P., 1999. The hydrology of the Nile. IAHS Special Publication No. 5, IAHS Press, Wallingford, UK.

Tennessee Valley Authority. 1947. *Malaria control on impounded water*. Washington D.C.: U.S. Government Printing Office.

Tharme, R.E.; King, J.M. 1998. *Development of the Building Block Methodology for Instream Flow Assessments and supporting research on the effects of different* *magnitude flows on riverine ecosystems*. Water Research Commission Report No. 576/1/98.

Turner, K.; Georgiou, S.; Clark, R.; Brouwer, R.; Burke, J. 2004. Economic valuation of water resources in agriculture. From the sectoral to a functional perspective of natural resource management. FAO Water Reports 27. Rome: Food and Agriculture Organization of the United Nations.

United Nations Development Program (UNEP) 2007. Comprehensive Options Assessment of dams and their alternatives. *Dams and Development Project. Workshop Proceedings September 22-24 2003, Geneva, Switzerland.* UNEP-DDP Secretariat, Nairobi, Kenya

Utzinger, J.; Tozan, Y; Singer, B. 2001. Efficacy and cost effectiveness of environmental management for malaria control. *Tropical Medicine and International Health* 6: 677-687.

Verrone, G. 1962a. Outline for the determination of malarial mosquitoes in Ethiopia. Part I. Adult female Anophelines. *Mosquito News* 22: 37-49.

Verrone, G. 1962b. Outline for the determination of malarial mosquitoes in Ethiopia. Part II. Anopheline larvae. *Mosquito News* 22: 394-401.

WAPCO; WWDSE, 2005. Environmental monitoring and resettlement plan for Koga irrigation and watershed management project, draft, Volume I and II.

Wardlaw, R.; Sharif, M.; Kimaite, F., 2005. Real-time hydro-power forecasting on the Victoria Nile, *Water Management* 158, pp. 45-54.

Water Works Design and Supervision Enterprise (WWDSE);ICT (2008). "Gumara irrigation project, final feasibility study report, volume III: water resources (a), annexure-7: meteorological and hydrological studies." Addis Ababa, Ethiopia.

Water Works Design and Supervision Enterprise (WWDSE); TAHAL (2008a). "Lake Tana sub-basin four dams project, final feasibility report for Ribb irrigation project, volume III: hydrological report." Addis Ababa, Ethiopia.

Water Works Design and Supervision Enterprise (WWDSE); TAHAL (2008b). "Lake Tana sub-basin four dams project, final feasibility report for Megech irrigation project, volume III: hydrological report." Addis Ababa, Ethiopia.

World Commission on Dams (WCD) 2000. Dams and Development: a new framework for decision-making. The report of the World Commission on Dams. Earthscan Publications, Thanet Press. London, UK.

World Bank. 2004. *Water resources sector strategy: strategic directions for World Bank engagement*. Washington, D.C.: The World Bank Press.

Yates, D.; Sieber, J.; Purkey, D.; Huber-Lee, A. 2005. WEAP 21 a demand, priority and preference driven water planning model, part 1: model characteristics. Water International 30, 487-500

Yohannes, M.; Mituku, H.; Ghebreyesus,T.A; Witten, K.; Getachew, A.; Byass, P.; Lindsay, S. 2005. Can source reduction of mosquito larval habitat reduce transmission of malaria in Tigray, Ethiopia? *Tropical Medicine and International Health* 10: 1274-1285.

PROJECT PARTICIPANTS

Solomon Kibret, Addis Ababa University
Yilma Seleshi, Addis Ababa University
Dereje Hailu, Addis Ababa University
Beyene Petros, Addis Ababa University
Jackie King, Southern Waters and University of Cape Town
Seleshi Bekele Awulachew, IWMI
Eline Boelee, IWMI
Solomon Seyoum, IWMI
Jonathan Lautze, IWMI
Benon Zaake, Directorate of Water Resources Management, Uganda.

Appendix A: Abstracts of key publications

Note author affiliations are correct at the time the publications were written

Peer Reviewed papers

**International Journal of River Basin Management* 5(3) (2007), 167–168

Dams, ecosystems and livelihoods

Jackie King[1] and Matthew McCartney[2]

[1] Southern Waters and University of Cape Town, Cape Town, South Africa
[2]International Water Management Institute, Addis Ababa, Ethiopia

Today, in a world of rapidly growing human numbers, wise management of freshwater is increasingly important. We face a major challenge of how to support national development goals, meet food needs, safeguard the livelihoods of rural people, and simultaneously protect an increasingly degraded environment. Against this background, the Challenge Program forWater and Food1 is an ambitious research and capacity building program that aims to significantly influence the use and management of water, particularly in agriculture. One part of this program is a project, presently underway, entitled *Improved planning of large dam operation: using decision support systems to optimize livelihood benefits, safeguard health and protect the environment*. The aim of the project is to conduct research to assess how decision support systems can improve the planning, design and operation of large dams in order to ensure sustainable use of river resources and improve equity in the distribution of benefits. The project partners are: Addis Ababa University, Ethiopia, the Ministry of Water Resources, Ethiopia, Southern Waters, South Africa and the International Water Management Institute. As part of its activities, the project organised an international conference in Nazaret, Ethiopia in January 2006, which focused on dams and decision support systems. The papers in this special issue emanate from the conference.

**International Journal of River Basin Management* 5(3) (2007), 169-178

Decision support systems for environmental flows: lessons from Southern Africa

Cate Brown[1] and Peter Watson[2]

[1] Southern Waters, Cape Town, South Africa
[2]PLW Development Solutions, Littlewick Green, UK

The decision by a number of countries to re-engage with large dams creates an obligation to ensure that the attendant environmental and social consequences are dealt with adequately. In this regard, the key challenges for the future are the assessment and management of downstream environmental and social impacts. The paper examines these issues in the context of southern Africa, particularly the Lesotho Highlands Water Project. It examines the ways in which Environmental Flows can affect the environment and the livelihoods of riparians, the need to make trade-offs between different uses of the water, and the difficulties of making trade-offs if the values of stakeholders regarding water use are not supported by a legal framework. The paper highlights the need to undertake environmental flow work early in the project cycle as part of the Environmental Impact Assessment, and the need to integrate environmental flow factors into the project's economic analysis. It explores the financial trade-offs that are implicit in environmental flow work, the need for a multi-disciplinary team to carry out the work, and the need for a transparent decision framework. Finally, the importance of establishing a decision support system for use during the operational phases of the project is highlighted.

**International Journal of River Basin Management* 5(3) (2007), 179-187

Decision support systems for managing the water resources of the Komati River Basin

Enoch M. Dlamini[1]

[1] Komati River Basin Authority, Melalane 1320, South Africa

The Komati River Basin is a trans-boundary watercourse shared by the Republic of South Africa (RSA), the Kingdom of Swaziland (KoS) and the Republic of Mozambique. The Komati Basin Water Authority (KOBWA) is charged with the management of the river basin under a treaty signed between RSA and Swaziland of which consent was given by Mozambique in a separate Agreement. KOBWA developed Decision Support Systems (DSS) to manage the system. These include DSS for: (i) long-term water allocation (yield model) between the countries, (ii) short-term water allocation (rationing model), and (iii) day-to-day water release (hydraulics model). An extensive water-monitoring program has been put in place to improve the effectiveness of these

DSSs. There has been a wide acceptance of the DSS by the users in the basin since the DSSs enable water users and water managers to make transparent water management decisions. This paper describes the three DSSs including the institutional framework on which these are applied.

**International Journal of River Basin Management* 5(3) (2007), 189-198

South African multi-stakeholder initiative in formulating policy on dams and development

Liane Greef[1]

[1] Water Justice Africa, Mowbray, South Africa

Following the release of the World Commission on Dams Report in November 2000: "Dams and Development A New Framework for Decision Making" a challenge was issued: "We have told our story: What happens next is up to you". In July 2001, South Africa took up this challenge with the hosting of a Multi-stakeholder Symposium on the WCD. At this symposium, South African stakeholders accepted the core values and approaches and declared themselves to be broadly supportive of the strategic priorities outlined in the WCD report, but believed that the guidelines needed to be contextualised in the South African situation. This resulted in the three-year South African Multi-stakeholder Initiative on the WCD Report and culminated in the Final Report entitled: "*Applying the WCD Report in South Africa*". This paper will share with the reader both the content of the South African Report as well as the remarkable process that enabled polarized perspectives to reach consensus on a broad range of controversial issues. It is this process that has been internationally recognized as a model for multi-stakeholder participation in policy formulation.

**International Journal of River Basin Management* 5(3) (2007), 199-206

Dams, health and livelihoods: lessons from the Senegal, suggestions for Africa

Jonathan Lautze[1] and Paul Kirshen[1]

[1] Tufts University, Medford, USA

Efforts in previous decades, largely culminating in the release of the World Commission on Dams Report [44], have engendered a more circumspect approach to dam construction and management—one which incorporates consideration for the environment, health, equity, stakeholders, and livelihoods. Such integration nevertheless often remains at a qualitative level, preventing tangible incorporation of these factors into Decision Support Tools (DSTs) for water management at a basin or sub-basin level. This paper uses the experience of the Senegal River Basin (SRB) to generate suggestions for how public health and smallholder livelihood concerns can be explicitly and quantitatively incorporated into dam planning and operations decisions in Africa's other basins. The study examines the operational tradeoffs made among livelihoods, health, and more conventional water needs such as irrigation and hydropower in SRB water management strategies over the last two decades. The examination of these tradeoffs is used to develop common health and economic metrics to aid water management decisions. In conclusion, suggestions are made for how use of these common metrics can enable DSTs in Africa's other basins to incorporate public health and smallholder livelihood parameters into dam planning and operations decisions.

**International Journal of River Basin Management* 5(3) (2007), 207-221

The state of the Colorado River ecosystem in Grand Canyon: lessons from 10 years of adaptive ecosystem management

Jeff Lovich[1] and Theodore S. Melis[1]

[1] United States Geological Survey, Flagstaff, USA

The year 2005 marks the 10th anniversary of the completion of the Final Environmental Impact Statement (EIS) on the Operation of Glen Canyon Dam on the Colorado River, USA. A decade of research and monitoring provides an important milestone to evaluate the effects of dam operations on resources of concern and determine if the desired outcomes are being achieved and whether they are compatible with one another or not. A comprehensive effort was undertaken to assess the scientific state of knowledge of resources of concern, as identified in the EIS. The result was the first systematic attempt by scientists to conduct an assessment of the changing state of Colorado River ecosystem resources in Grand Canyon over a decadal timeframe. In the EIS, 30 resource attributes are listed along with predictions for how those resources would respond under the Secretary of the Interior's 1966 Record of Decision, an operating prescription based on the preferred alternative of Modified Low-Fluctuating Flows (MLFF). Because of a lack of data or subsequent analyses to confirm whether some predictions stated in the EIS were correct, or not, 14 or 47 percent of the outcomes, are essentially unknown. Excluding outcomes that are unclear, then the remaining predictions in the EIS were correct in 7 out of 16 outcomes, or 44 percent of the categories listed. Mixed outcomes occur in 4 out of 16, or 25 percent of the categories, and failed predictions, occur in 5 out of 16, or 31 percent of the categories. As such, less than 50 percent of the outcomes were predicted correctly, underscoring the uncertainties associated with working in a large complex system with few to no long-term data sets. Similar

uncertainties are faced by all resource managers charged with ecosystem restoration globally. The acceptability of this kind of uncertainty is influenced by interpretation, societal values, agency missions and mandates, and other factors. However, failure to correctly predict the future, in and of itself, is not deleterious under the paradigm of adaptive management where large uncertainties provide opportunities for learning and adjustment through an iterative process of "learning-by-doing" (Walters and Holling, 1990). Although recent science has documented a continued decline of environmental resources of the Colorado River below Glen Canyon Dam, it has identified options that might still be implemented by managers to achieve desired future conditions in Grand Canyon.

*International Journal of River Basin Management 5(3) (2007), 223-233

Quantifying well-being values of environmental flows for equitable decision-making: a case study of the Hamoun wetlands in Iran

K.S. Meijer[1] and S. Hajiamiri[1]

[1] Delft University, Delft, the Netherlands

Construction of dams and reservoirs affects various groups of people. People who are often the losers from construction and operation of dams are the users of downstream ecosystems. To consider the needs of these people in water resources decision-making, the relationships between water, ecosystem and human well-being need to be assessed. This should lead to quantified criteria scores to support the decision-maker. Current environmental flow assessment methods focus on the relationship between water and ecosystems, but leave a gap where quantifiable criteria on human well-being are concerned. This paper discusses an approach for quantifying the effect of changed flow regimes on human well-being in an Integrated Water Resources Management study in Iran. The study shows the different effects on different groups of people, and in this way contributes to the consideration of social equity in decision-making in Integrated Water Resources Management.

*International Journal of River Basin Management 5(3) (2007), 235-244

Monetary benefit sharing from dams: a few examples of financial partnerships with indigenous communities in Québec (Canada)

Dominique Égré[1], Vincent Roquet[2] and Carine Durocher[2]

[1] Dominique Égré Consultants Inc., Saint Laurent, Canada
[2] Vincent Roquet & Associates Inc., Saint Laurent, Canada

Development practitioners have long recognised that the undeniable benefits of infrastructure projects based upon resource extractive activities, such as dam projects, often carry an associated price tag in terms of environmental and socio-economic impacts on communities in their area of influence and on taxpayers in general. Beyond the mitigation and compensation of negative impacts, sponsors increasingly recognise the need for directly sharing project benefits with local communities. The economic rationale for benefit sharing is the existence of an economic rent. Other justifications for benefit sharing include: a) the need for fair redistribution of benefits to negatively affected populations; and b) the need for financing development investments over and above mandatory compensation for damages and losses. This article discusses mechanisms that ensure a direct monetary redistribution of project-related revenues or profits from dam projects to project-affected populations. A review of international case studies reveals that such mechanisms may pursue one or several of the following objectives: (a) providing additional long-term compensation to affected populations; (b) establishing a partnership with local communities based on sharing of the economic rent generated by the dam project and (c) establishing long-term regional development funds. The review also reveals that the following five types of mechanism may be considered: (a) revenue sharing; (b) development funds; (c) equity sharing; (d) taxes paid to local or regional authorities; and (e) preferential electricity rates and other water-related fees. The article illustrates the revenue sharing and equity sharing forms of benefit sharing mechanisms with two examples of financial partnerships with Indigenous communities in the province of Québec, Canada: the Paix des Braves Agreement between the Government of Québec and the Grand Council of the Crees and the Minashtuk project.

*International Journal of River Basin Management 5(3) (2007), 245-250

Licensing for dam construction and operation – practical decision support developed and improved over 100 years

Bjørn Wold[1], Rune Flatby[1], Thomas Konow[1] and Kristian Løkke[1]

[1] Norwegian Water Resources and Energy Diretorate (NVE),Oslo, Norway

During the last 100 years some 2500 dams have been built in Norway either related to irrigation, domestic and industrial water supply, or hydropower development projects, the latter being the dominant. A legal and regulatory system has been developed and amended to serve the ever changing policies and needs of a country that during the last century has been transformed from one of the poorest in Europe into one of the

richest in the world. The needs and interest of the affected local population and their rightful share of the benefits of the hydropower development project have been taken care of in various ways over the years, from providing new houses and electricity, to the construction of new roads and even direct payments. The dams normally constructed in relation to these projects are monumental structures built to last for a very long time, some would say forever. In order to avoid dam breaks and thereby assure public safety, a legal framework securing appropriate operational rules, compliance with technical requirements and periodic inspections of the dams is an absolute necessity. A transparent government licensing process, involving all public and other stakeholders, is of crucial importance in order to achieve general acceptance of a project. The process includes comprehensive impact studies on environmental and social issues, as well as appropriate technical and political issues related to the eventual implementation of the project. Granting of a license should be based on a clear and unambiguous conclusion that the total benefits of the project exceed the negative impacts. The license includes explicit conditions stating a set of operating rules and other precautions that assure technical safety and environmental sustainability. All conditions are subject to revisions.

Tropical Medicine and International Health, 12(7) (2007), 1-10,

Effect of a large dam on malaria risk: the Koka reservoir in Ethiopia

Jonathan Lautze[1], Matthew McCartney[2], Paul Kirshen[1], Dereje Olana[3], Gayathree Jayasinghe[2] and Andrew Spielman[4]

[1]Department of Civil and Environmental Engineering, Tufts University, Medford, Massachusetts, USA
[2] International Water Management Institute, City??, Ethiopia
[3] Department of Vector-Borne Diseases, Oromia Health Bureau, Ethiopia
[4] Harvard School of Public Health, Boston, Massachusetts, USA

OBJECTIVE To determine whether the Koka water reservoir in the Rift Valley of Ethiopia contributes to the malaria burden in its vicinity.
METHODS Frequency of malaria diagnosis in fever clinics was correlated with distance of residence from the margin of the Koka reservoir. Annual as well as seasonal malaria case rates were determined in cohorts residing < 3, 3–6 and 6–9 km from the reservoir. Plasmodium falciparum risk was compared with that of Plasmodium vivax. A multiple variable regression model was used to explore associations between malaria case rates and proximity to the reservoir, controlling for other suspected influences on malaria transmission.
RESULTS Malaria case rates among people living within 3 km of the reservoir are about 1.5 times as great as for those living between 3 and 6 km from the reservoir and 2.3 times as great for those living 6–9 km from the reservoir. Proximity to the reservoir is associated with greater malaria case rates in periods of more intense transmission. Plasmodium falciparum is most prevalent in communities located close to the reservoir and P. vivax in more distant villages. The presence of the reservoir, coupled with inter-annual climatic variations, explains more than half of the region's variability in malaria case rates.
CONCLUSION Large water impoundments are likely to exacerbate malaria transmission in malariaendemic parts of sub-Saharan Africa.

Hydrological Processes
published online (www.interscience.wiley.com) DOI: 10.1002/hyp.7254 (2009)

Estimating environmental flow requirements downstream of the Chara Chara weir on the Blue Nile River

Matthew McCartney[1] Abeyu shiferaw[2], Yilma Seleshi[3]

[1]International Water Management Institute, Addis Ababa, Ethiopia
[2]Independent consultant, Addis Ababa, Ethiopia
[3]Addis Ababa University, Addis Ababa, Ethiopia

Over the last decade, flow in the Abay River (i.e. the Blue Nile) has been modified by operation of the Chara Chara weir and diversions to the Tis Abay hydropower stations, located downstream. The most conspicuous impact of these human interventions is significantly reduced flows over the Tis Issat Falls. This paper presents the findings of a hydrological study conducted to estimate environmental flow requirements downstream of the weir. The *Desktop Reserve Model* (*DRM*) was used to determine both high and low flow requirements in the reach containing the Falls. The results indicate that to maintain the basic ecological functioning in this reach requires an average annual allocation of 862 Mm^3 (i.e. equivalent to 22% of the mean annual flow). Under natural conditions there was a considerable seasonal variation, but the absolute minimum mean monthly allocation, even in dry years, should not be less than approximately 10 Mm^3 (i.e. 3.7 m^3 s^{-1}). These estimates make no allowance for maintaining the aesthetic quality of the Falls, which are popular with tourists. The study demonstrated that, in the absence of ecological information, hydrological indices can be used to provide a preliminary estimate of environmental flow requirements. However, to ensure proper management, much greater understanding of the relationships between flow and the ecological condition of the river ecosystem is needed.

Water Policy 11(1) (2009), 121-139

Living with dams: managing the environmental impacts

Matthew McCartney[1]

[1]International Water Management Institute, Addis Ababa, Ethiopia

Dams, through disruption of physiochemical and biological processes, have water and associated environmental impacts that have far reaching social and economic consequences. The impact of each dam is unique. It depends not only on the dam structure and the attributes of local biota but also climatic and geomorphic conditions. Given the number of existing dams (over 45,000 large dams) and the large number that may be built in the near future, it is clear that humankind must live with the environmental and social consequences for many decades to come. This paper provides a review of the consequences for ecosystems and biodiversity resulting directly from the presence of dams on rivers, and of constraints and opportunities for environmental protection. It illustrates that a wide range of both technical and non-technical measures has been developed to ameliorate the negative impacts of dams. It argues that relatively few studies have been conducted to evaluate the success of these measures and that it is widely perceived that many interventions fail, either for technical reasons or as a consequence of a variety of socioeconomic constraints. It discusses the constraints to successful implementation and mechanisms for promoting, funding and ensuring compliance. Finally, it contends that there is a need to improve environmental practices in the operation of both existing and new dams.

IWMI Research Reports

Malaria transmission in the vicinity of impounded water: evidence from the Koka Reservoir, Ethiopia (RR 132, 2009)

Soloman Kibert[1], Matthew McCartney[2], Jonathan Lautze[3] and Gayathree Jayasinghe[4]

[1] University of Addis Ababa, Addis Ababa, Ethiopia
[2]International Water Management Institute, Addis Ababa, Ethiopia
[3]International Water Management Institute, Colombo, Sri Lanka
[4]Independent Consultant, Colombo, Sri Lanka

The construction of dams in Africa is often associated with adverse malaria impacts in surrounding communities. However, the degree and nature of these impacts are rarely quantified and the feasibility of environmental control measures (e.g., manipulation of reservoir water levels) to mitigate malaria impacts has not been previously investigated in Africa. This report describes entomological and epidemiological research conducted in the vicinity of the Koka Dam and Reservoir in Ethiopia. Key findings of the study include: a) substantially greater malaria case rates observed in communities close to the reservoir; b) greater abundance of malaria vectors found in community dwellings close to the reservoir as a consequence of breeding habitats created along the reservoir shoreline; and c) faster falling water levels are associated with lower mosquito larval abundance in shoreline puddles. These findings confirm the role of the reservoir in increasing malaria transmission and suggest there may be potential to use dam operation as a tool in integrated malaria-control strategies.

Evaluation of current and future water resource development in the Lake Tana Basin, Ethiopia (in press)

Matthew McCartney[1], Tadesse Alemayehu[2], Abeyu Shiferaw[3] and Seleshi Bekele Awulachew[1]

[1]International Water Management Institute, Addis Ababa, Ethiopia
[2]Independent consultant, Addis Ababa, Ethiopia

Lake Tana is valuable for many people, including the communities who live around the lakeshore, those living on islands and close to the Blue Nile River, which flows from it. The area has been identified as a region for hydropower and irrigation development, vital for food security and economic growth in Ethiopia. This report presents findings from an integrated multi-disciplinary study conducted to investigate the implications of this development. The study comprised three components: i) an environmental flow evaluation; ii) a stakeholder analysis of the impact of current infrastructure and water management, and iii) computer modeling of future water resource development. The study found that existing water resource development (primarily for hydropower generation) has modified flows downstream of the lake, reduced lake water levels and significantly decreased flow over the Tis Issat Waterfall. Interviews with stakeholders indicate that the changes have benefited some people but adversely affected others. Future development will exacerbate pressure on the lake. If all the planned development occurs, the mean lake water level will drop by 0.44 m and the average surface area will decrease by 30 km^2 (i.e. 1%) and up to 81km^2 (i.e. 2.6%) in some dry seasons There will be prolonged periods of several years during which water levels will be much lower than they would be naturally. If environmental flow requirements (estimated to average 862 Mm^3y^{-1}) are maintained in the reach containing the Tis Issat Waterfall, the mean lake water level will reduce by a further 0.37 m and the average lake area by an additional 26 km^2. Without careful management these changes are likely to have severe ecological and

social consequences. Hard choices must be made about how the water is best utilized. It is important that all stakeholders (including local people) are involved in the decision-making process and benefit from investments.

IWMI Working Paper

Decision Support Systems for Large Dam Planning and Operation in Africa (WP 119, 2007)

Matthew McCartney[1]

[1]International Water Management Institute, Addis Ababa, Ethiopia

In recent years, great emphasis has been placed on the need to improve the management of the environmental and social impacts of large dams. This is particularly important in Africa where there is a drive to build more and yet many people continue to rely on those natural resources which are impacted by dams for their livelihoods. The environmental and consequent social impacts of large dams are often complex and extremely difficult to predict. Dam planners and operators often have to consider a huge number of factors and often conflicting objectives, which makes decision-making problematic. In such situations, decision support systems (DSS) have an important role to play. Over the years, many different DSS have been developed for dam planning and operation. This report presents a review of the different types of DSS and their application in water resource management. Although some information and examples have been obtained from elsewhere, the main focus is Africa. The report is not intended as a comprehensive compendium on DSS application in dam planning and operation. Rather, it provides an overview and framework for understanding issues pertaining to decision-making in relation to large dams in Africa.

CPWF Working Paper

Use of Decision Support Systems to improve Large Dam Planning and Operation in Africa (under review)

Matthew McCartney[1] and Jackie King[2]

[1]International Water Management Institute, Addis Ababa, Ethiopia
[2] Southern Waters and University of Cape Town, Cape Town, South Africa

Current low levels of water storage in Africa correspond to high levels of poverty. Despite this, the role of large dams for poverty alleviation and socio-economic development remains controversial. This controversy stems from the fact that although numerous positive benefits can be attributed to large dams, in the past dams have also resulted in profound adverse impacts for those, invariably poor and voiceless, people living close to and downstream from them. It is now widely acknowledged that a key goal of any large dam must be to ensure that it provides a development opportunity for *all*. However, planning and operating large dams to ensure this is extremely difficult. The recommendations made in this report relate to seven key issues pertaining to dam planning and operation: i) strengthening stakeholder involvement in decision-making processes, ii) improving EIAs, iii) improving consideration of downstream environmental and social impacts, iv) taking better account of possible public health impacts, v) improving options assessment, vi) improving mechanisms for benefit sharing, and vii) improving water resources management in transboundary basins.

Papers from the International Nile Basin Development Forum (Khartoum, 3-5 November, 2008)

Evaluation of the water budgets of the equatorial lakes of the White Nile

Zaake Tamukedde Benon[1] and Matthew McCartney[2]

[1]Directorate of Water Resources Management, Entebbe, Uganda
[2]International Water Management Institute, Addis Ababa, Ethiopia

The Hydrologic Model of the Upper Nile Equatorial Lake Basin was developed to simulate the hydrologic regime of this area. The model is able to simulate the natural behavior of the major lakes in the region. It is intended that the model will, in future, be used to assess various lake regulation alternatives that could be considered in the quest to optimize the balance between hydropower production and protection of lake ecosystems. Some of the data requirements for this model are monthly estimates of total inflow to the lakes, outflows, changes in storage, rainfall and evaporation. This paper describes the preparation of data required by the model. Analyses were constrained by the lack of long time series of data. Nevertheless, new estimates of the water budgets of Lakes Edward and George are presented. A review of the water balance of Lake Albert was also undertaken. Updates to the water budgets of Lakes Victoria and Kyoga, from recent studies, are also included in order to compile all available historical data within the basin.

Evaluation of Impacts and Assessment of Environment Flow Requirements downstream of the Chara Chara Weir on the Blue Nile

Abeyu Shiferraw[1] and Matthew P. McCartney[2]

[1]Addis Ababa University. Addis Ababa, Ethiopia
[2] International Water Management, Addis Ababa, Ethiopia

Over the last decade flow in the Abay River (the Blue Nile) has been modified by operation of the Chara Chara weir and diversions to the Tis Abay hydropower stations, located downstream of the rivers source, Lake Tana. The upstream regulation and diversions have significantly reduced flow over the Tis Issat Falls, a major tourist attraction. This paper presents the findings of a survey conducted to determine the socio-economic impacts caused by the alteration of flows and the results of a hydrological study conducted to estimate environmental flow requirements in the reach containing the Falls. The study found that changes in the flow regime have affected entitlements to natural resources and the environmental quality experienced by communities living downstream of the weir. Although some local people have gained benefits, little consideration has been given to those adversely affected. The results of the Desktop Reserve Model indicate that to maintain the basic ecological functioning of the reach containing the Falls requires an average annual allocation of 862 Mm^3 (i.e. equivalent to 22% of the natural mean annual flow) and an absolute minimum flow of not less than 3.7 m^3s^{-1}. Currently these flow requirements are not being attained.

Papers from the 2nd International Forum on Water and Food (Addis Ababa 9-14 November, 2008)

Major Impacts of the Chara Chara Weir and Environmental Implications

A. Shiferaw[1], M. McCartney[2], Y. Seleshi[3] and Z. Woldu[4]
[1]Independent Consultant, Addis Ababa, Ethiopia
[2]International Water Management Institute, Addis Ababa, Ethiopia
[3]University of Addis Ababa, Addis Ababa, Ethiopia

Over the last decade flow in the Abay River (the Blue Nile) has been modified by operation of the Chara Chara weir and diversions to the Tis Abay hydropower stations, located downstream of the rivers source, Lake Tana. The upstream regulation and diversions have significantly reduced flow over the Tis Issat Falls, a major tourist attraction. This paper presents: i) the findings of a survey conducted to determine the socio-economic impacts caused by the alteration of flows and ii) the results of a hydrological study conducted to estimate environmental flow requirements in the reach containing the Falls. The results indicate that to maintain the basic ecological functioning of the reach containing the Falls requires an average annual allocation of 862 Mm^3 (i.e. equivalent to 22% of the natural mean annual flow) and an absolute minimum flow of not less than 3.7 m^3s^{-1}. Currently these flow requirements are not being attained.

EIA follow up in the Koga irrigation project, Ethiopia

W.B. Abebe[1], M.McCartney, W.J.A.M. Douven[3], J. Leentvaar[3]

[1] ANRS Bureau of Agriculture, Bahir Dar, Ethiopia
[2]International Water Management Institute, Addis Ababa, Ethiopia
[3]UNESCO-IHE, the Netherlands

In Ethiopia, environmental impact assessment (EIA) procedures are generally properly considered and result in well-formulated environmental impact statements and plans. However, the implementation of proposed mitigation measures and monitoring of actual environmental impacts form a weak link in the EIA process. As a result projects still cause negative environmental impacts. This paper reports on a study of the follow-up of EIA-recommended mitigation measures in the Koga irrigation and watershed management project. The research found that the EIA documents, which were prepared during the feasibility study, were generally satisfactory. However, one weakness in the EIA was the poor estimation of flow requirements downstream of the dam. The analyses conducted as part of the EIA neglected both the natural variability of flow and the livelihoods of people dependent on fisheries. Furthermore, many of the activities planned in the EIA have not subsequently been implemented in a satisfactory manner. Lack of consultation and public participation was found to be a major constraint to implementation of EIA recommendations. To improve the sustainability of the project attention needs to be given to improving: public participation, regulatory activities and institutional arrangements.

Mosquitoes and malaria in the vicinity of the Koka reservoir, Ethiopia.

Solomon Kibret[1], Matthew McCartney[1] and Jonathan Lautze[2]

[1]International Water Management Institute, Addis Ababa, Ethiopia
[2]Tufts University, Boston, USA

To determine the impact of the Koka reservoir, Ethiopia, on malaria transmission, larval and adult *Anopheles* mosquitoes were collected fortnightly between August 2006 and December 2007 in two villages close to the reservoir (< 0.8 km) and two control villages, situated farther away (>7 km). During the study, the mean number of positive larval sites was 6.5 times higher in the reservoir villages than in the control villages. Shoreline puddles were the major mosquito breeding habitats in the reservoir villages, while temporary puddles, formed during the wet season, served as the major breeding sites in the control villages. Throughout the study, larval and adult mosquito densities were significantly higher in the reservoir villages than in the control villages. In the reservoir villages, both vector abundance and malaria case rates were found to be correlated with water-level changes in the reservoir. When reservoir water-levels were high, drawdown rates faster than 0.5 m/month correlated with lower vector abundance and reduced malaria transmission. These findings indicate the possibility of using dam operation as an additional tool for reducing malaria in communities close to the reservoir.

Enhancing stakeholder participation in regulation studies of the Equatorial lakes

B. Zaake[1] and M. McCartney[2]

[1]Directorate of Water Resources Management, Entebbe, Uganda
[2]International Water Management Institute, Addis Ababa, Ethiopia

Over the past decade, the application of systems analysis techniques and Decision Support Systems to support the operation of existing and planned dams in the Upper Nile Equatorial Lakes Basin, has been recognized as an important step towards the quantification of the costs and benefits of different operating options. However, there has been very limited progress towards implementation of the regulation regimes proposed by such DSS. This is partly because: i) there is no basin-wide framework to support consideration and adoption of new regulation strategies, and ii) social and environmental concerns have not been considered. This paper presents the findings of a consultative exercise designed to agree upon broad management objectives for regulating the Equatorial Lakes within a participatory problem structuring framework. Representatives of different stakeholder groups were able to rank decision criteria and agree on priority concerns. The process was facilitated through the use of an objectives hierarchy methodology, commonly referred to as Value Trees. The findings provide a sound foundation on which to base further development of a Decision Support System for this basin.

* Paper in special edition of the International Journal of River Basin Management (2007). These papers were written for the International Working Conference: *Enhancing equitable livelihood benefits of dams using decision support systems*, which was organized by this project 23-26 January 2006 in Adama/Nazareth, Ethiopia.