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Critical analysis of environmental flow assessments of selected rivers in Tanzania and Kenya

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By Chris Dickens

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Pangani River Basin Management Project

The Pangani River Basin Management Project is generating technical information and developing participatory forums to strengthen Integrated Water Resources Management in the Pangani Basin, including mainstreaming climate change, to support the equitable provision and wise governance of freshwater for livelihoods and environment for current and future generations.

The Pangani Basin Water Board is implementing the project with technical assistance from IUCN (International Union for Conservation of Nature), the Netherlands Development Organization (SNV) and the local NGO PAMOJA. The project is financially supported by the IUCN Water & Nature Initiative, the Government of Tanzania, the European Commission through a grant from the EU-ACP Water Facility, and the Global Environment Facility through UNDP.

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Table of Contents

Summary

This report represents a summary and analysis of work that has been carried out over the past decade or so, to assess and implement the environmental flow requirements of four river basins in Tanzania. These basins are the Pangani, Great Ruaha, Wami and the Mara (shared with Kenya).

As the research and management efforts in each of the basins was essentially independent from the others, the approach to the investigations has been unique in each situation. Similarly, the reporting of this information has been unique, in some cases published by international donor agencies, in others in refereed literature and in other cases by the basin authorities themselves.

In order to review these four largely dissimilar studies, this report has chosen to structure the review of each basin in a standard way following a format based on the "classical" environmental flow process used to determine and implement environmental flow management.

The Pangani basin study was probably the most directed, working within a well structured work plan to understand the information and to derive the environmental flow requirements. Uniquely, this study also chose to house all of this within possible scenarios for the basin, thus presenting the information in a format that is immediately accessible for management to make choices. The project also undertook extensive training of local personnel, again adding to a capability to implement. On the negative side, the approach used was relatively complex which may make it less accessible to management in the longer term.

The Wami basin study was seen as a pilot study for Tanzania. This project, with a relatively small budget, achieved a great deal that can be productively used for the management of resources in the Wami River. The project was not only limited by available funds but also by poor background data, thus making the determination most challenging. The approach used was relatively simple but appropriate for the situation.

The Great Ruaha study passed through two phases, the first where a low confidence approach was used for the determination, and then, in August 2010 a report became available that described an extensive project just being completed. This project directly faced the many challenges being experienced in the Ruaha, produced direction on environmental flows and has even taken these forward to management of a complex situation. A large amount of excellent information exists describing the water needs of this basin, which has now potentially been brought together to make effective management of the basin possible.

The Mara river assessment is complicated as it is a trans-boundary basin, dominated by issues that are taking place in Kenya upstream. Large amounts of information are available on general catchment issues, but only recently have clear reports on the environmental flow requirements been produced. Good works is taking place and it is probable that the next few years will provide even greater detail on environmental flows, particularly for Tanzania, so that this information can start to be effective in management.

The review report which follows below provides a detailed assessment of the work that has been done, and includes an assessment of the limitations of each study. The report ends with a critical analysis of the situation in the whole of Tanzania, with some recommendations for the way forward.

As an overall conclusion though, it has to be said that the initiative and progress to determine environmental flow requirements for rivers in Tanzania, and also to implement them, has been exemplary. Water resource managers and scientists had clearly recognised that many water resources in the country were being threatened and indeed were no longer providing the services to people that they should have been, thus prompting this extensive programme of research to solve the problem. The work that has been done has been creative and well considered. Yes, there is more to be done, but the resource cannot wait until the science has been completed. Tanzania can be proud of this endeavour which can be seen as a leading example of how a country can tackle the issue of environmental flows and how this integrates with effective resource management.

Introduction

During 2010 The Institute of Natural Resources based in Pietermaritzburg, South Africa, was contracted by the IUCN – ESARO to undertake a review of the work done on environmental flows in Tanzania. The main objectives of this study were:

1. A critical anaylsis of environmental water requirement studies and assessment that have been carried out in Tanzania including the Pangani, Wami, Mara and Ruaha basins and catchments.

2. Dissemination of lessons learned and discussion on current environmental flows assessments

3. A series of recommendations on implementing environmental flows and operationalizing the concept.

This report was a first step to achieving the above objectives. This was followed by a process of interaction with stakeholders in order to disseminate lessons learned but also to refine the way forward. The International Union for Conservation of Nature (IUCN) in collaboration with the Pangani Basin Water Board, and the Ministry of Water and Irrigation of Tanzania held a 2 and a half days workshop on "The Future of Environmental Flows: Providing water for Nature and People" from August 2nd to 4th, 2010 in Morogoro, Tanzania. Outputs from this workshop were used to strengthen the review report.

In order to introduce the subject of environmental flows, a good place to start is the definition as contained in the Tanzania Water Resource and Management Act (2009), which defines the "Reserve" for rivers as:

"Reserve" means the quantity and quality of water required for:

(a) satisfying basic human needs be securing a basic water supply for people who are now or who shall in the reasonably for (sic) near future, be-
a. relying upon
b. taking water from, or
c. being supplied from the relevant water resources: and
(b) protecting to protect (sic) aquatic ecosystem in order to secure ecologically sustainable development and the use of the relevant water resource. ……. i.e. those water volumes and flows (and quality) that are required to maintain the very ecosystem that the provision of benefits is dependent on.

NOTE: This review is a contracted review of a number of defined projects that have taken place. It is not a review of the general literature. Because of this, there has been free copy and insertion of text from these reports into this report, in order to demonstrate the contents of those reports. There is no claim that these are the words of the author of this report. In most cases, but not in all, these words have been referenced to the document of origin. In some cases, the context of the insertion makes its origin obvious. All of the documents which have been reviewed are included in the Bibliography at the end of this report.

The Brisbane Declaration (2007) provides a useful description of environmental flows: "Environmental flows describe the quantity, quality and timing of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems". This definition acknowledges the linked variables of quantity, quality, and timing that together constitute an environmental flow regime of sufficient quality to meet management goals.

At first appearances it may seem like a simple task to secure a portion of a river flow for basic human needs and to protect the aquatic ecosystem. However, all ecosystems are the result of thousands of years of interaction between physical, chemical and biological components of the ecosystem in a way that may be unique to a small section of an individual river. Thus, to determine the Reserve or environmental flow requirement, this has to be done uniquely for each approximately homogeneous reach of river. To make matters more complicated, these flow requirements change during the course of the year, different in each season and also different in wet and drought cycles. Thus has evolved the science of environmental flow assessment, a process whereby the quantity and quality of a water resource required to maintain the ecosystem on which society depends, may be determined.

Countries all over the world have taken up the challenge of determining and implementing environmental flows, and it is written into the law books of many. As is the tendency with any new creative science, the approaches to doing this are many and varied, some successful and others less successful, some operating at a minimalist and others at a complex level.

In Tanzania, the determination and implementation of environmental flows is just beginning. A number of parallel initiatives have been started and the environmental flows of four rivers given priority i.e. the Pangani, Wami, Great Ruaha and Mara rivers. In most of these, the foundation science has been undertaken, making use of a variety of different methods and approaches. The next priority will be implementation, where the science has to align with political and socio-economic priorities in order to be implemented on the ground.

This report thus reviews the approaches to environmental flows that have been adopted in the different basins, the science that was used and the way that this is being carried towards implementation.

NOTE: "Environmental Flow", "EF", "Environmental Water Allocation", "Environmental Flow Assessment", "Environmental Water Requirement", "Instream Flow Requirement" and "Reserve" are terms commonly used interchangabley, and are treated so within this report. While there may be real differences in meaning e.g. Reserve expressely includes Basic Human Needs and also the quality of the water, which may not be considered by other terms, in this report the context where the phrase is used should make the meaning clear.

Structure of this report

Each of the Tanzanian rivers is allocated a separate chapter within this report. In order to streamline a review of the work, it is prudent to bring all of the reporting on the rivers into a common structure so that they may be compared. The structure of this report is thus based on a classical environmental flows assessment, where each section is presented sequentially as it would be carried out during an EF study. The structure of reporting on each river is as follows:

Section A – Initiation and scope of studies.

Section B - Process to define areas of study and assessment.

Section C - Evaluation of the original and present state of the systems.

Section D - Evaluating the importance and sensitivity of the systems.

Section E - Quantifying the environmental flow requirements.

Section F - Setting a vision for the river and development of scenarios.

Section G - Implementation of environmental flows.

Section H - Monitoring issues.

Section I: Successes, limitations and gaps.

Chapter 1. The Tanzanian Situation

The common feature for all rivers in Tanzania where environmental flows (EF) have been considered, is the National legal context. This can be summarised as follows:

National Water Policy (NAWAPO 2002)

This Policy gives substantial support to the protection of environmental flows and provides the critical thinking and principles on which the later Water Resources Management Act (2009) are derived. Key provisions in the Policy that are pertinent to the protection and implementation of environmental flows include:

2. The main objective of this revised policy is to develop a comprehensive framework for sustainable development and management of the Nation's water resources, in which an effective legal and institutional framework for its implementation will be put in place.

   In-stream flows or environmental flows and levels are necessary for riparian biodiversity, wetland systems, freshwater-seawater balance in deltas and estuaries. Reduction of water volume affects aquatic life by reducing dissolved oxygen and supply of nutrients (Section 1.2.2.8).

   Sustainable water development and use implies that the actions of the present generation to develop and use water resources are taken in such a way as to ensure that the present and future generations enjoy the benefits of this vital resource (Section 1.2.3.1).

   In view of the issues and challenges in water resources management it is clear that an integrated water resources management is needed to ensure that water does not become a constraint to national development. This calls for ***a new vision "A country where there is equitable and sustainable use and management of water resources for socio-economic development, and for maintenance of the environment" (emphasis added)***. It recognizes that water is a scarce resource and integrates the linkage between land use and water use and recognizes the important role water ecosystems play in the national economy (Section 1.2.3.2).

Policy issues in water resources management

The objective of the policy for Water Resources Management is to develop a comprehensive framework for promoting the optimal, sustainable and equitable development and use of water resources for the benefit of all Tanzanians, based on a clear set of guiding principles. The specific objectives include (amongst others): (i) To develop equal and fair procedures in access and allocation of the water resources. (ii) To ensure that social and productive sectors, and the environment receive their adequate share of the water resources.
The policy makes a clear statement about the prioritization of water use, following on from provision for basic human needs, it states that "Water for the environment to protect the ecosystems that underpin our water resources, now and in the future will attain ***second priority*** and will be reserved. Other uses will be subject to social and economic criteria, which will be reviewed from time to time."
It goes on to say "In order to ensure that water resources are used in a sustainable manner, conserved and that ecological system and biodiversity are sustained, water management approaches will focus on how best water is used beneficially and efficiently. Water allocations and use shall be carried out considering the principles of sustainability so that the resources remain viable for the use of the present and future generations." It also says that "the quality and quantity of water resources will be dealt with conjunctively, and will be assessed comprehensively." Giving this greater emphasis, it says that "Water ***for the environment***, in terms of quantity and quality, and levels, and for both surface and groundwater resource shall be determined on the best

scientific information available considering both the temporal and spatial water requirements to maintain the health and viability of riverine and estuary ecosystems, and associated flora and fauna."

The policy then gives some direction to the institutional framework for the management of water resources. The relevant institutions include:

National Level

The Ministry with the mandate for water is responsible for managing the nation's water resources. It will determine policy orientation, development and time-to- time review of policy and legislation, preparation of conducive environment, sectoral coordination and integration, and sectoral planning, National water assessments and planning; data collection and dissemination, monitoring and evaluation, establishment and maintenance of water resources databases and information management systems, preparation and implementation of training programs, and preparation of Regulations.

WATER RESOURCES MANAGEMENT ACT, 2009*

This Bill was Gazetted and passed in April 2009 and gives definition to an Act designed to aid implementation of the National Water Policy, which includes the following important provisions that are aimed at protection of the water resource: The new Act intends to ensure that the nation's water resources are protected, used, developed, conserved, managed and controlled for basic human needs for the ***present and future generation***.

The Act is divided into sixteen parts. Part II gives principles and objectives of water resources management which include the principle of protecting biological diversity especially of aquatic ecosystems as well as preventing and controlling water pollution and degradation of water resources. It also recognizes that ecosystem integrity is an essential part of sustainable water resources development. Part IV provides for the management of water resources including the institutional framework. Of note is that it is the responsibility of the Director of Water Resources to formulate policies and programmes aimed at management and development of water resources and control of water pollution, and to ensure that these adhere to the principles of environmental sustainability. He/she also has to ensure protection of water resources of National interest. Of interest is that the Basin Water Boards are required to "maintain and update assessments of the availability and potential demand for water resources".

Part VI (a. Water Resources Classification and Reserve) provides for protection of water resources which includes water resources classification and reserve *(definition provided in the section above)*, establishment of protected zones, declaration of groundwater controlled areas and prevention of pollution. This includes that the Minister can Gazette the classification of a resource, specify the resource quality objectives of the class to which the resource belongs, and the requirements for achieving these objectives. It is also the Ministers responsibility to ensure that the reserve is established and that the determination of the reserve should "ensure that adequate allowance is made for each aspect of the reserve" *(this is potentially ambiguous unless clarified)*. The Minister then passes this responsibility to all public bodies to take account of and give effect to the requirements of the Reserve.

**Note that this Act was not presented in most of the project reports as it is was only Gazetted in 2009*

Basin Level

Since water resource management and development will be undertaken on the basis of river basins, this is the level for data collection, processing and analysis, water allocation, pollution control, preparation of water utilization plans, collection of the various fees and charges, and resolution of various water related conflicts. The present system of managing through Basin Water Boards will be strengthened.

Catchment Level

The large size of River Basins makes water management difficult since Basin staff are distant from water users. In order to remedy this, catchment Water Committees and sub-catchment Water Committees will be established, and will be composed of representatives from the public and private sector, and from the Water User Associations within the respective Basin.

Water Resources Management Act, 2009

Following the National Water Policy in 2002, the Water Resources Management Act (2009) has given effect to this Policy and also replaces the

Water Utilization (Control and Regulation) Act No. 42 of 1974 and its subsequent amendments. The new Act corrects many of the inadequacies of the old Act especially in terms of resource protection and sustainable use.

Below is an extract from the Tanzanian Environmental Management Act of 2004, which also gives powers to manage and protect environmental flows and related aspects of water resources.

From the above, it can be seen that Tanzania has followed an evolutionary process in refinement of its policy. The National Water Policy (2002) was a well considered document that contained a presentation of the thinking that included the protection of the aquatic ecosystem that is the source of the water related benefits to society. This presentation was done via the description of principles and objectives, and contained discussion about the strengths and weakness of the old Act of 1974.

The resulting Water Resources Management Act (2009) is a refined document that gives effect to these policy ideals. In terms of protection of ecosystems and environmental flows, it is clear that these take second place only to the provision of basic human needs, and that all other water allocations follow after this provision.

The Act (2009) places the responsibility on the "Minister responsible for water resources" but in effect the responsibility rests with the Director of Water Resources, the National Water Board and Basin Water Boards. The latter is responsible for implementation issues but strategic direction needs to come from the Director of Water Resources.

The decision making processes that led to the development of the reserve and environmental flows for the rivers which have already been investigated, (Pangani, Ruaha etc), predated the Act (2009) and were a response to the Water Policy and global trends. These studies have involved the perception of a need within basin management and even within the people of the basin. Government and other local structures have been well supported by international agencies such as the IUCN and WWF to carry out these projects. It is clear from this, that there is ample provision within the law for the assessment and implementation of environmental flows.

Tanzanian Environmental Management Act 20 of 2004

161. For the purpose of environmental management where the need arise for the creation of easement on a burdened land, the authority to which that land is subject may request the Minister to issue environmental conservation order so as to-

(a) preserve flora and fauna;

(b) preserve the *quality and flow* of water in a dam, lake, river or aquifer;

60. (1) Every applicant for water use permit issued under the relevant laws governing management of water resources, abstraction and use of water, shall be required to make a statement on the likely impact on the environment due to the use of water requested.

60. (3) Basin Water Boards in prioritising different uses of water shall ensure that adequate water is made available for environmental purposes.


2 m
3 m
4 m

Chapter 2. The Pangani River

Section A: Initiation and scope of studies

The Pangani Basin Water Board (PBWB)[1] staff have been supportive of the EFA initiative and have taken part in many of its studies. In this they have the support of National legislation as documented above and there is strong support from at least one Member of Parliament. The PBWB have also been responsible for publication of the many reports which have been reviewed here, working with the IUCN. A business plan for the PBWB to take environmental flows into implementation has been worked on but was not accessed for this review.

The Pangani River Basin Management Project (PRBMP), supported by the IUCN Water & Nature Initiative, UNDP/GEF and the European Union, made a commitment to conduct a flow assessment in the Pangani Basin as a means of providing relevant technical information (hydrological, economic, ecological and social) to the Pangani Basin Water Board to support the water-allocation process. Details of the objectives of the project are presented below.

At an early stage it was decided that the full DRIFT method (Brown et al 2005), which is a holistic approach considering scenarios related to environmental flows, was too complex and also that there was insufficient data, so a scaled down version would be applied. This was a pragmatic approach that was intended to provide a tool that would be appropriate to the Tanzanian situation.

The objectives of the Pangani Basin Flow Assessment (FA) were to:

1. generate baseline data on the condition of rivers, wetlands and the estuary against which the impact of water-related decision-making can be monitored in future;
2. enhance the understanding among PBWO and MoW staff of the relationship between flow, river health and the people who use the river;
3. create an awareness of the trade-offs to be made between water development and natural-resource protection;
4. develop simple tools to help guide water-resource management and water allocations in the Pangani River Basin;
5. build capacity that will enable PBWO to act as a nucleus of expertise for FA related work in other areas;
6. support the National Water Policy (NAWAPO 2002) and the National Environmental Management Act (2004).

[1] *As of 2010, the Pangani Basin Water Office (PBWO) is referred to as the Pangani Basin Water Board, hwoever in this report the PBWO is still referenced.*

The above objectives are strongly service and capacity building orientated. For example, point 2 indicates that the objectives is to enhance understanding of the relation between flow, river health and people, but does NOT undertake to actually quantify that relationship. Likewise, point 3 was to create an awareness of trade-offs, not specifically to quantify them. In fact, the resulting project appears to go further than these objectives.

Section B: Process to define areas of study and assessment

An objective of the Pangani study was to divide the river into relatively homogeneous zones in terms of biophysical characteristics (river reach analysis) and land-use, and homogeneous zones across the basin in terms of social factors; to select representative sampling sites in the river zones, in the estuary and in each social zone; and to develop simple (GIS) base maps for use in subsequent tasks.

An in-depth report on the process of basin delineation was produced (Baseline delineation report - PBWO/IUCN, 2008a). The basin was divided both into ecological and socio-economic zones, which were then integrated into 10 zones which were divided into 31 sub-zones and 3 estuarine sub-zones. One or more sites were located in each of these sub-zones, selected on the basis of their accessibility and representivity.

The following information was used in the overall delineation:

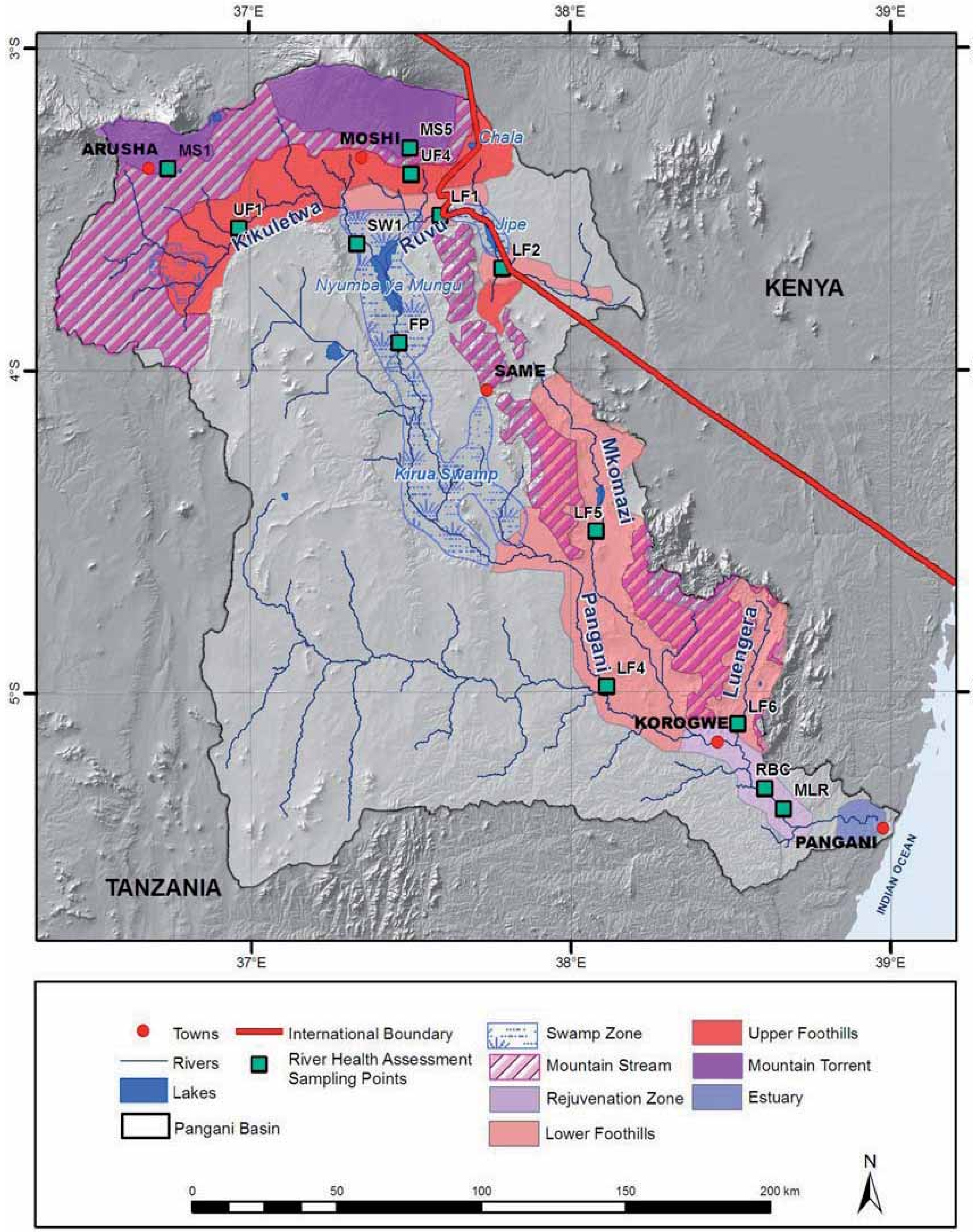
- Administrative districts
- Topography and rainfall
- Climate
- Location of rivers, wetlands and dams
- Distribution of vegetation

The rivers were then zoned according to the following criteria

- Hydrological zonation (catchments)
- Geomorphological and hydraulic zonation which included the geology, substratum, channel and river morphology, slope. The longitudinal profiles of each river were plotted, and the changes in slope used to indicate different zones.
- Chemical and thermal zonation. A limited number of existing reports were used to provide the data used for this zonation. Six zones were defined on this basis.
- Biological zonation – based on existing data and reports but none were full in their descriptions. The report indicates the paucity of information on the biota e.g. the upper zone Mountain Streams did not turn up any biological information at all. Even the lower zones had little biological information, sometimes limited to crocodiles and a few birds.
- Harmonised zonation – combining all of the above into 10 zones including the estuary. The estuary was subdivided into 3 sub-zones based on salinity and estuary morphology.

Socio-economic zonation was carried out using the following:

- Population
- Land use
- Use of water
- Household use



The zonation of rivers and estuary of the Pangani basin illustrating the sample sites as well.

The ecological and socio-economic zones were synchronized to ensure the optimum matching of data and information.

Sites on the rivers were selected for different purposes. For the river health assessment – 13 river sites were selected (including lakes and swamps (wetlands)). The estuary was sampled rather more intensively, with 12 sites. For the social survey, sites including a total of 30 villages distributed evenly between the zones were surveyed. Note that a number of river sub-zones were not sampled – each with a unique reason e.g. no hydrological data, difficult to access, dominated by a dam.

Criteria to consider when selecting sites for a river health assessment (PBWO/IUCN 2007b)

The site should:

- be representative of the streams or rivers in the zone - this implies that homogeneous regions within the geographic area under consideration need to be identified.
- If a *reference* site, i.e. representing the natural or least-impacted condition, the site should be minimally-disturbed,
- If a *monitoring* site, the site should capture the anthropogenic impacts in the particular river reach or zone. *Note: if localised impacts at a site such as a bridge modify the site to the extent that the more general impact in the reach is not likely to be assessed, then an alternative site should be sought.*
- have an appropriate variety of biotopes and substrates.
- be relatively accessible and safe during sampling operations.
- if a *reference* site, if possible, have a natural channel and stable banks.
- if a *reference* site, possible, have a natural hydrograph.
- if a *reference* site, possible, have natural riparian vegetation.

The site could also:

- have links to existing on-going monitoring projects, e.g. water quality monitoring
- be situated nearby flow gauging stations (in order to link with existing hydrological and water chemistry data).

Section C: Evaluation of the original & present state of the systems.

It is acknowledged that most river systems have departed in condition somewhat from their pristine condition. In the experience of most countries, this departure is in many cases quite severe so that many of the original benefits of the pristine river have been eroded to the point where the river provides much reduced benefit to society. In the setting of environmental flow requirements, it is usually accepted that there needs to be some knowledge of the original pristine condition of the river ecosystem. This information makes it possible to determine just how far the river has changed from its original condition and also provides information on the nature of the ecosystems that are known to thrive in a particular zone of the river, even if these are no longer present. This evaluation often includes the following:

- Quantity of water in the river, at different times of the year, seasonal changes etc
- Quality of the water
- The biota in the river which are directly linked to the presence of the water in the river
- The habitats which provide a home for these biota.

All of the above may be brought together to provide a synthesized value to represent the ecological state of the river at any particular time. The original, natural condition of the river would naturally provide the upper end of a continuum of possible change, the lower end of which would be complete collapse of the river ecosystem and the present state somewhere in between.

The methods used for the Pangani assessment (PBWO/IUCN 2007b) are based on those developed in the River Health Programme of the National Aquatic Ecosystem Health Biomonitoring Programme of South Africa. The method involves the collection of information necessary to characterise a site, to provide an indication of catchment condition and land-use, together with relevant abiotic (water quantity and quality) and biotic (invertebrates, fish, riparian vegetation) information. Survey was carried out in the Pangani in the wet and dry seasons.

Following the analysis of the data collected for each of the components assessed, it was reported that a discussion was held to determine the status of each of the components using common categories to indicate the level of modification from an expected natural or baseline condition (A - Natural, unmodified system; B - Largely natural, slightly modified system; C - Moderately modified system; D - Largely modified system; E* - Only for IHI – Seriously modified system; and F* - Only for IHI - Critically modified system).

At each site, the channel was classified primarily based on its morphology and sediments, and the condition of the immediate catchment was determined using the IHI. The hydraulic nature of the site was determined by measuring a cross section and calculating the flow at different parts. A basic water quality condition was also established at the site and a single sample also sent for analysis. This all enabled a meaningful description of the river site to be collected which would help with understanding of the flow requirements for that site.

Hydrology

A hydrological model of the Pangani River Basin was configured, calibrated, and used to produce long-term flow sequences at 15 key points in five main catchments (the Ruvu, Kikuletwa, Mkomazi, Luengera and Pangani) with 15 sub catchments. The study was designed to extend the available flow records (which were insufficient and also confused by changing abstractions) by means of monthly rainfall/runoff modeling. The representative rainfall records were long enough to produce long-term "naturalised" and "current day" flow sequences of about 76 years in length.

A water resources balance was determined for 5 sites which are the downstream limits of each of the above five catchments. A confounding issue of the hydrology of this basin was that a portion of the water in the river does not actually leave the basin, and has been termed endorheic (Definition: from the Greek: éndon, "within" and rheîn, "to flow", is a closed drainage basin that retains water and allows no outflow to other bodies of water such as rivers or oceans). In the Pangani, wetland areas form in localised low points or "sinks" where water is captured and does not appear at the outlet of the catchment. This compounds the hydrological investigation, as some of the measurable flow in the river does not make it to the exit from the catchment, for natural reasons.

Table 4.1 of the hydrology report (PBWO/IUCN 2006a) is potentially confusing, e.g. for the Mainstem it says that there is Natural runoff including endorheic runoff (830) and endorheic on its own of (1425), with the latter being larger than the former. The derivation of this is not clear. Then, Cumulative Natural Runoff is calculated with the formula of <Natural runoff including endorheic plus natural upstream inflows MINUS endorheic runoff>. According to Cate Brown (*pers com 2010*) the understanding is that the natural runoff does not include endorheic runoff. Hence, in the case of the Kirua swamps, flood waters would have been trapped in the swamps and would never have become runoff in the downstream river. Although some waters may have drained back into the river as lowflows, the bulk of the water would have eventually evaporated or evapo-transpirated, i.e., lost from the system. Since the floods were very large, the amount trapped could well have exceeded the natural runoff.

Summary – the project was able to calculate extensive statistics of the flows, the losses, the abstractions, water demand, return flows etc. all resulting in a percentage utilisation. There was a total of 76 years of data to do this with.

Graphs illustrating present and naturalized flows which were produced are very illustrative and useful, showing the various occurrences of different flow volumes in the various months, comparing natural and present day. This type of information is essential for the evaluation of the cause of change in the responding ecosystem, and is used in the determination of environmental flow requirements.

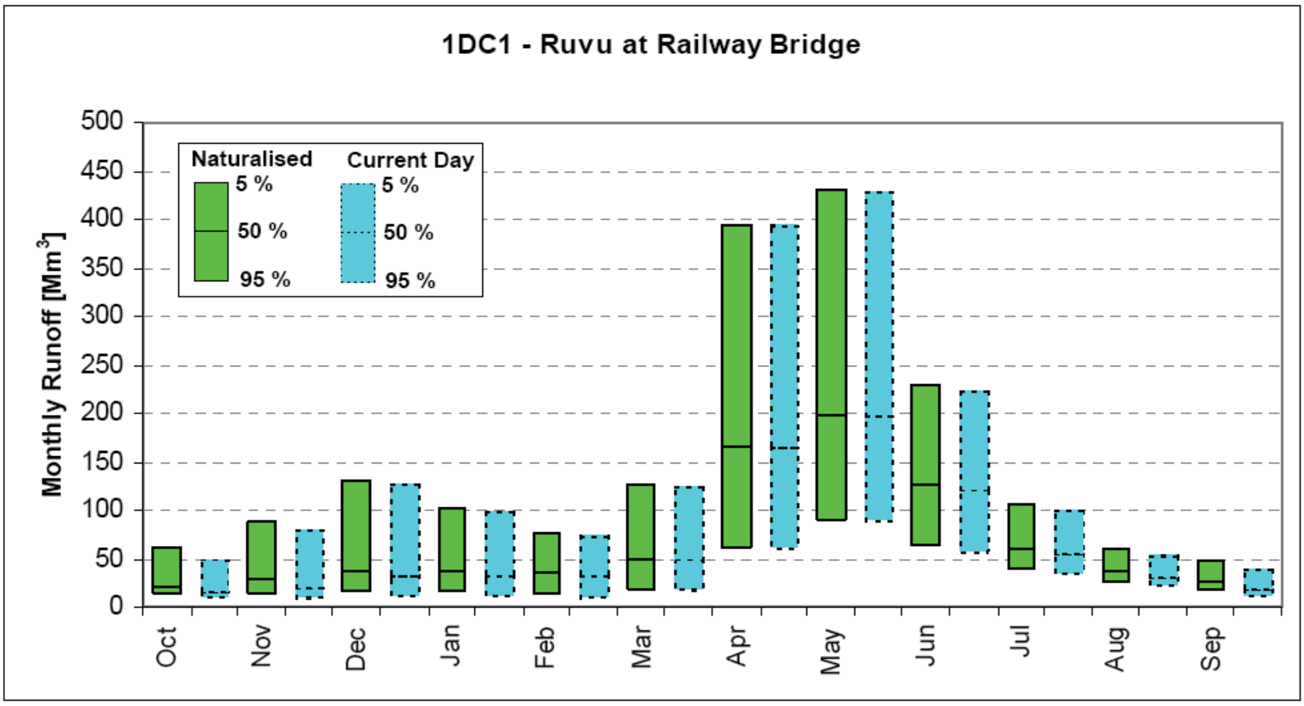


Figure E.4. : Comparison of Naturalised and Current Day Flows - Ruvu

The management of the hydrological data has been identified as an issue and suggestions have been made to streamline and make this more secure. The quality of the hydrological data was also recognized as a deficiency but this was considered by the project team not be a major flaw to the assessment of the environmental flow. The main point is that the data could provide an indication of the use of water in the basin and the impact that this has had on the flow regimes.

The long term monthly data was used for the scenario planning and for the systems modeling. These monthly flow data had to be disaggregated into daily flows in order to make ecological sense. This was done with the aid of measured daily flow records. A detailed specialist report was produced (PBWO/IUCN 2006a).

Hydrological data is abundant and complex and generally requires the use of models to assist with interpretation. A process of model selection was followed to decide on which model would be used in the Pangani Programme. The Pitman rainfall-runoff model (within the Shell model) was selected – using a monthly time step. From this, catchment models were calibrated to generate natural rainfall runoff and alterations due to catchment developments. MIKE BASIN model was selected to do the systems analysis, but due to its complexity, the WEAP model was selected as an alternative. WEAP is also considered to have strong scenario evaluation facilities.

Water quality

Existing water-quality data collected at key points along the river was used for this interpretation.

The suite of water quality variables used was comprehensive enough for a study of this nature, and included: pH; Conductivity; Temperature; Dissolved; Oxygen; Suspended solids; Turbidity; Nitrate; Ammonia; Total P; Sulphate; Flouride; Total Fe; Mn; Ca; Mg; Carbonate and bicarbonate; Chloride and Chlorophyll.

Hydraulic habitat

The standard DRIFT method requires that cross sections of the river sites are surveyed in order to understand the relationship between river channel form and flow discharge characteristics. This information forms the foundation of the understanding of environmental flow requirements by the various ecologists, yet there is little presentation of such information and its use in this study.

A separate report on the hydraulic characteristics of the lakes and swamps in the Pangani has been produced in order to establish the flow needs to maintain these systems. This report is documented in Kimaro et al (2008).

Substrate habitats

The project investigated the habitat suitable for invertebrates following the approach of the IHAS method – but adapted by Dallas (2007). The aim of the IHAS assessment is to record details about the SASS biotopes sampled, which are divided into stones in current, vegetation and other (stones out of current, gravel, sand, mud).

An assessment was also made of the substratum composition. This includes a simple representation of the nature of the substratum, which is useful in determination of the flow requirements of the biota (see below).

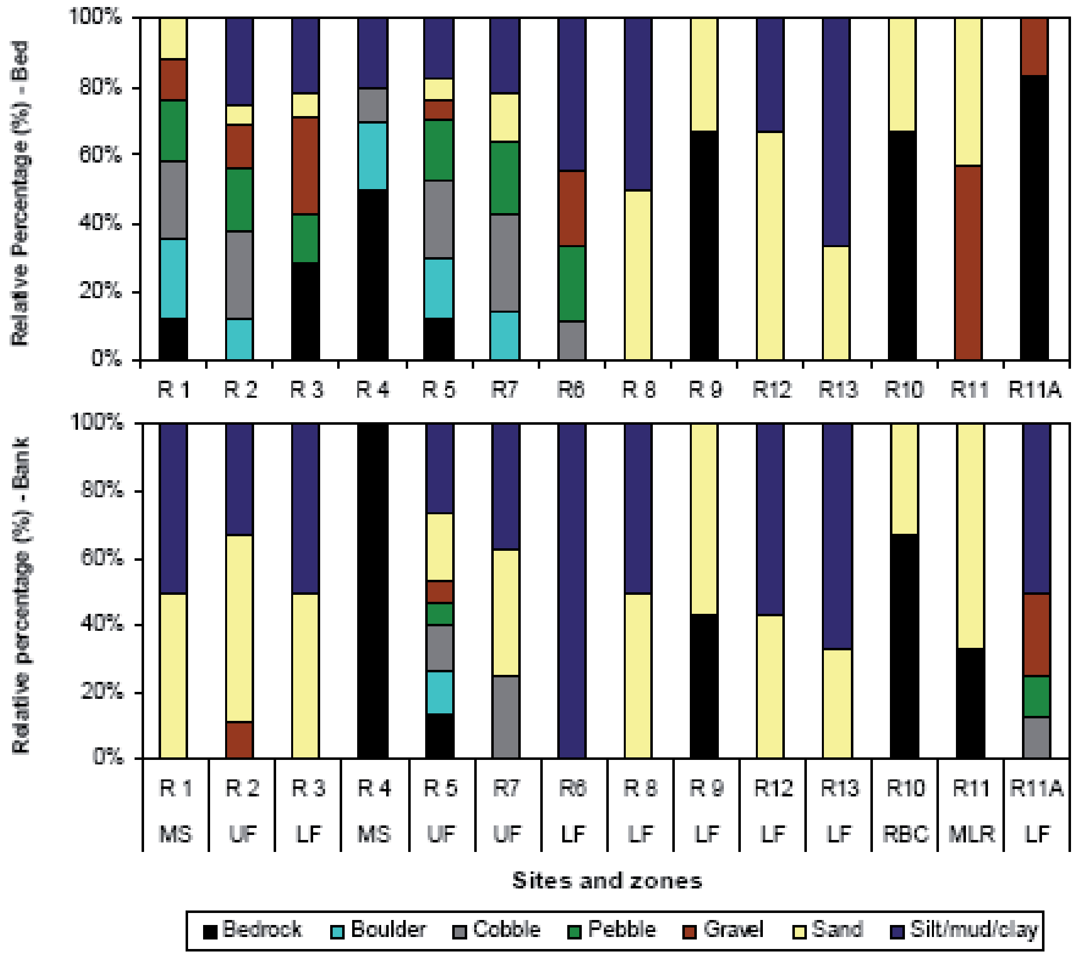


Figure 3.32 Relative percentage of each substrate type for the bed and bank. These percentages are based on the rating scales used to rate the abundance of each substrate.

Fish habitat was also recorded, based on the abundance or otherwise of flow depth classes as well as vegetation and substrate type.

General habitat integrity

The instream and riparian habitat integrity is roughly indicated by making use of a simple index. This includes indicators of the modification of the bed, riparian vegetation, changes in flow etc. This type of simple index synthesizes a great deal of information into a format where the overall integrity of the habitat at a site can be compared with others. It is not designed to be accurately quantitative.

Biota

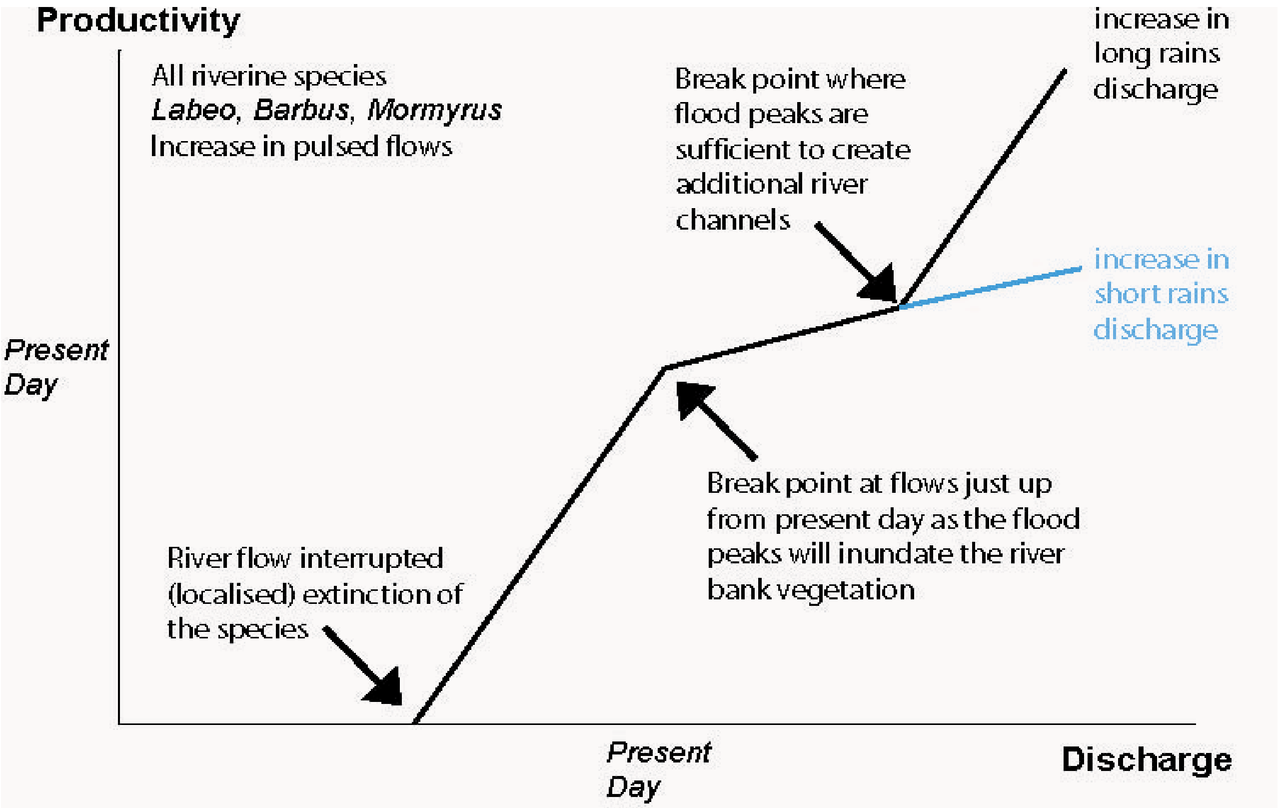
The following biological information was also collected:

Invertebrates were monitored using the SASS method which gives an indication not only of the invertebrate diversity at a site, but also reflects the "health" of the ecosystem particularly resulting from water quality impacts, but also due to habitat conditions. Three aspects are considered when applying the SASS method:

- an assessment of the biotopes present at the site,
- an assessment of the invertebrates present in each biotope (SASS5), and
- an assessment of the biotopes sampled (IHAS).

Fish were sampled in the available velocity depth classes. A variety of methods were used including electro-fishing in the dry season, and sein, sweep and gill nets. Fish were also collected from local fishermen. The fish assessment was based on existing information and a single 5 day survey.

In the fish report, an attempt is made to provide graphs that chart the response of key guilds in the system to changes in flow (see below). The central point in each graph is the current situation labeled as "present day". The x-axis represents "discharge" and the y-axis represents an unspecified measure of "productivity".



Neither of the axes is parametric and changes from the present day situation should be read as increase, decrease or stability. No quantitative interpretation in the sense of doubling, tripling or percentage increases can be derived from them, only the three trends mentioned above though changes in slope indicate stronger responses. A distinction is made between pulsed and non-pulsed flows as the response curves are predicted to be very different under these two types of discharge. This type of graph is useful in ensuring that the range of possibilities for a species are considered in relation to flow changes – and the best available knowledge of this documented in this way. As mentioned above, they do not claim to be quantitative representations. Note that this is NOT done per species, but rather for guilds of species. It is done separately for rivers, floodplains and estuary.

Vegetation – a qualitative assessment of each site in the field was collected. The plan was to assess the vegetation cover, species composition, identify invasive plant species and describe habitat stratification. The study used existing vegetation data of the Pangani River Basin to first describe the longitudinal distribution of the riverine species within the vegetation communities, categorizing them into terrestrial and aquatic, then describing the longitudinal and lateral distribution of the species within vegetation communities in five longitudinal zones of the basin i.e. mountain stream etc. Later the drivers of change in this system were identified as well as the ecologically and socio-economically important plant species. Conceptual Models were then developed that show how different species in the different zones of the Pangani River basin will respond to different flow regimes in different seasons (response curves were produced for indicator species). What is not indicated in the report, is how these curves are derived – whether this is an actual measurement or whether this is an estimate by expert judgment. These curves are used as input to the Flow Assessment Tool.

In summary - the situation at each site is presented with a comprehensive overview of the river health coupled with photographs. Following this is a summary of the TRENDS of local catchment and site characteristics. Appendix F provides a very useful list of questions and answers related to all the aspects of the river in relation to environmental flows. This approach captures well the nature of the sites in a narrative and understandable way that will be useful in later interpretation of these reports.

Estuary Health Assessment

This was based on two surveys of ecological characteristics in the high and low flow periods. This information was assimilated using the South African DWAF (2004) estuarine method to produce an Estuarine Health Score. The results for the estuary place the estuary into a “largely modified” category. The detailed Estuary Health Assessment report (PWBO/IUCN. 2007a) documents the hydrology, sediments and channel morphology, water quality, vegetation, invertebrates, fish and birds which characterize the estuary.

Estuary Water quality

Samples were collected at high and low tides at different depths at each site. Note that the details of the water quality (WQ) methods, procedures etc have not been assessed in this review as it is assumed these are standard.

Biota

Vegetation was assessed during a two day survey in the high season. The main objectives of the survey were to classify and map the vegetation types occurring within the estuary as well as to identify the main species present. Other objectives included identifying the principal factors responsible for structuring vegetation communities in the estuary, as well as assessing whether patterns observed have been modified in any way by anthropogenic activities. Speculating on future trends and possible changes in the vegetation of the estuary was also part of the assessment. Vegetation classification, mapping, species identification and other assessments were conducted.

Zooplankton – were collected after sunset at high tide during high and low flow seasons.

Benthic invertebrates – were collected using a benthic corer or a grab sampler during both high and low flow seasons.

Fish – were collected using sein and gill nets during the high and low flow seasons.

Birds – identification was *ad hoc* during travels around the estuary.

The results are presented in a very useful table (a portion of which is below) describing the Present State compared to the Reference Condition for all the abiotic and biotic components. These scores are then weighted and summed to determine the Health Index.

5.1 Description of Present State and Reference Condition

5.1.1 Abiotic Components

Hydrology

Variable	Score	Motivation	Confidence
a. % similarity in period of low flows or Present MAR as a % of MAR in the Reference Condition	86	Based on modelled river flow for the period 1929-2004 (76 years), PBWO/IUCN (2006) report a marked reduction in dry season high flows and wet season low flows reaching the estuary, mostly due to flood interception at Nyumba ya Mungu and Kalimawe Dams. Dry season low flows reportedly show relatively small reductions, in part due to contributions from the Luengera catchment, but also due to hydropower releases from Nyumba ya Mungu Dam. Overall reduction in mean annual runoff reaching the estuary is estimated to be 86% of the reference condition.	Medium
b. % similarity in mean annual frequency of floods	86	The currently day flooding regime has been significantly modified from the natural situation. Mostly severely affected are the small to medium sized floods, as is evident from the differences in flow peaks between the current day and naturalized monthly flows in the period for which modeled flows are available. Monthly flows in the range 100-125 m^3 are down 14% in the current day versus naturalized flows, those in the range 125-150 m^3 are down by 6%, those in the range 150-175 m^3 are down by 3%, and those in the range 200-225 m^3 are down by 2%. Monthly flows larger than all this differ by <1% from the naturalized flows. Considering the importance of the medium to small-scale floods a percentage of 86 has been allocated.	Medium
Hydrology score	**86**		

Summary of the biophysical estuary assessment - these studies are very comprehensive describing almost every aspect of the river from a physical, chemical and biological point of view. This level of detail assists with interpretation of flow requirements.

Socio-economic situation

A detailed study of the macro-economic situation in the Pangani was carried out by Kahyarara and Eusebi (undated). The prime objective of the macroeconomic study was to provide technical inputs needed to; i) assess the economic contribution of the Basin, ii) to provide the general assessment of systems of water allocation and management and iii) to undertake the basin flow assessment. Specifically the study provides a detailed overview of the economy of the Pangani River Basin, and the contribution that this area makes to the national economy, quantifies the relationships between water supply and sectoral outputs at a micro and macro-scale and finally provides a working, user-friendly model with which to evaluate the regional and national economic consequences of changes in water allocation, which would take changes in agricultural, hydropower and fisheries production into account, as well as any other important water user sectors. This model provides a useful and necessary high-level perspective on the determination of environmental flows.

A second report in greater detail was produced on the economic status of the basin and is detailed in PBWO/IUCN. 2007c.

The basin was divided into 6 homogeneous zones and the economies for each documented. While aquatic ecosystems generate various types of value, this study concentrated only on the value of water and aquatic natural resources to rural households in the basin. Because the Pangani River Basin Flow Assessment Initiative is largely concerned with how water allocation affects the livelihoods of people in the basin, this study only examines information from a **direct consumptive use value of aquatic ecosystems to rural households**. This was done via a combined literature and household survey process. Data and information was collected from household surveys which included 659 households. An element of capacity building was promoted in the use of several local persons.

The socio-economic survey and report are very extensive. This includes the value of water related natural resources which enables decision making with regard to the allocation of flows. They also discuss the effect of water resource changes on the economy and in particular on household income and analyse the trade-offs in the allocation of resources. This information is used later to estimate the impacts of different water allocation scenarios on rural livelihoods and the economy. The authors do acknowledge though that limitations of this and preceding studies will mean that the analysis of trade-offs will be limited in some respects and that future research will be necessary to fill important gaps. Particularly relevant would be to know more about the full suite of goods and services provided by the river as only direct consumptive use was considered, not other non-consumptive aspects such as recreation, tourisms and indirect uses such as waste dilution.

Section D: Evaluating the importance and sensitivity of the systems

Possibly missing from the Pangani river assessment is a broad overview of the importance of this system from a conservation/sustainability point of view. Does the system contribute to the local and broader biodiversity from a point of view that it is important for the long term sustainable use of the system? This question has not been fully addressed.

For the estuary there are strong concerns of the changes that have taken place, and recommended improvements, but this is not in relation to the broader regional perspective i.e. how the status of this estuary needs to be considered as part of regional conservation plans. The Task 5 report (PBWO/IUCN 2008c) noted that predicted changes to the river ecosystem are assessed in terms of national commitments to multilateral environmental agreements (e.g. UNCBD, UNFCCC, UNCCD, Ramsar Convention) as well as national policies, legislation, strategies and plans in relevant sectors (e.g. water, energy, agriculture, environment).

Section E: Quantifying the relationship between river flow and the ecosystem.

It is important at the outset to confirm that the approach adopted for the Pangani River Basin was to follow the DRIFT model (Brown et al 2005). This approach has a particular set of characteristics that differ substantially from other approaches such as the BBM (King et al 2008). The main difference is that while the BBM approach documents the water requirements to maintain the ecosystem in a particular condition, DRIFT on the other hand describes the consequences to the ecosystem of adopting a particular flow scenario. Both methods nevertheless, require that an understanding of the relationship between river flow and the ecosystem response should be developed.

For the Pangani, the various river health investigations concluded with documenting the relationship between the different biophysical aspects and the flows in the river. Initially, this was reported in a qualitative way, describing without any attempts to quantify the relationship. Later, in the models themselves, more quantitative relationships are presented.

Because the DRIFT model in its entirety was considered to be too intense for the Pangani project, the project set out to design a custom built DSS for the purpose of evaluating the environmental flows of the Pangani (The Pangani Flows DSS User Manual – see Southern Waters et al (undated)). This DSS also summarises flow-related knowledge and expertise into a custom-built FA database. This model was also designed to query the database to evaluate the impact of scenarios on the ecosystem, the users of the ecosystem AND the economy.

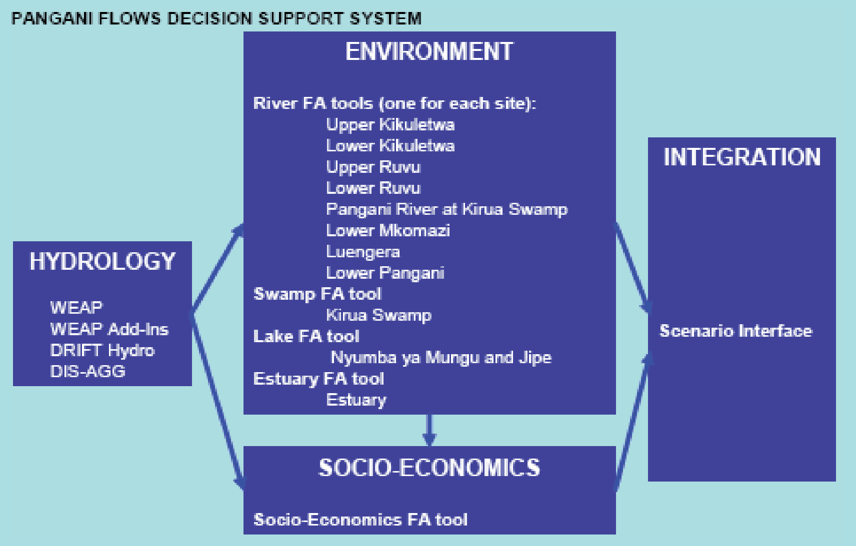


Figure 3.1 Basic structure and components of Pangani Flow DSS

The report contains a number of models (as indicated in the figure above). For example, the River FA tools which are used for analysing the implications for the river of different flow regimes. There are eight River FA Tools, each dealing with one river site. This DSS links together a wide range of information to allow the assessment of scenarios (see later).

Section F: Setting a vision for the river and development of scenarios.

Vision for the basin

The Tanzanian legislation and the objectives of the PBWO give a broad framework to a vision for the resources of the country and for the Pangani Basin, but a detailed vision for the river, developed with the people who share in its resources, has not been set. Such a vision would describe the characteristics of the river including the benefits it would provide to the people who rely on it. Setting of a vision for the rivers of any basin should be the first step in the development of a strategy for management including development of scenarios. DRIFT provides a model whereby different scenarios can be investigated to see how they would impact on the environment but it does not explicitly seek to address a pre-determined vision for the river. While it could be argued that this could end with the same result and that the DRIFT approach would ensure that the vision is achievable, it could also be argued that the setting of a vision should not be constrained by the vagaries of data and information, but should reflect the will of society. DRIFT would then determine if the vision can be met or not.

Scenarios for the basin

This part of the project in the Pangani was to consider the different development scenarios and the consequences for the environment and in this way to facilitate decision making for how the basin should be managed.

Two main reports document the scenarios, PBWO/IUCN 2006b and PBWO/IUCN 2008b.

The project selected a number of scenarios that considered the range of possibilities for the basin if different components of the system were to be given priority. The scenarios are descriptions of possible future water-use pathways in the basin, with their ecological, social and economic benefits and costs. The report does qualify its results by stating that none of these scenarios is certain to happen but that they are best predictions of possible development paths, which planners and decision-makers can consider in order to identify a preferred path and strategise to achieve it. The scenarios thus outline options for the future, and do not make recommendations of which should be chosen. This choice is a value judgment to be made by the Tanzanian government, in consultation with the stakeholders of the basin.

There was an intensive stakeholder consultation process at the start of this project, designed to ensure that stakeholder concerns were identified so that they could be included within the description of each scenario. The information offered by stakeholders was used to guide the data-collection exercise and to design scenarios that address their concerns. Stakeholders listed the problems with water in the basin and also the trends.

In most cases each development scenario was run for two different ecosystems demands:

1. with aquatic ecosystems receiving the residual water;

2. with the environmental flow requirements for aquatic ecosystems receiving a second-priority allocation (only after basic human needs).

Predictions were made regarding the likely consequences of changes in flow using existing biophysical and socio-economic information, supplemented by specialist understanding and local knowledge. The various streams of information and predictions were organised within a custom-built Decision Support System (DSS). Ultimately, each scenario – or development pathway - could be described in terms of the predicted consequences to hydrology, river condition, the economics of the natural resources of the river, HEP generation, irrigated agriculture, and social impacts.

Fifteen scenarios were selected. These all included Basic Human Needs (BHN), Domestic, Industrial, Agriculture and Hydroelectric Power Generation (HEP) as major categories of users. Some sites also included pre-estimates of the environmental flow – in those cases where environmental flows were considered to be the major portion of the flow.

Within the Pangani DSS, the Scenario Interface brings all of the scenarios and components together and summarizes the results. This includes the production of summary sheets of eco-indicator changes – used to document the actual changes in abundance of an element of the ecosystem in response to a scenario. The Eco-integrity score then tells if this is a change towards or away from the natural relative to the present day. This is all integrated into an overall summary – an example being presented below, showing the summarised percent changes in Integrity, Social and Economic effects of each scenario for the whole basin (PBWO/IUCN 2008b).
A note of concern is that the figure below materially differs from a figure intended to illustrate the same outcomes but presented in the Pangani Flows DSS User Manual (Southern Waters - undated). While this was not intended to be a report on the actual outcome of the project, the discrepancies between these two results are concerning and confusing.

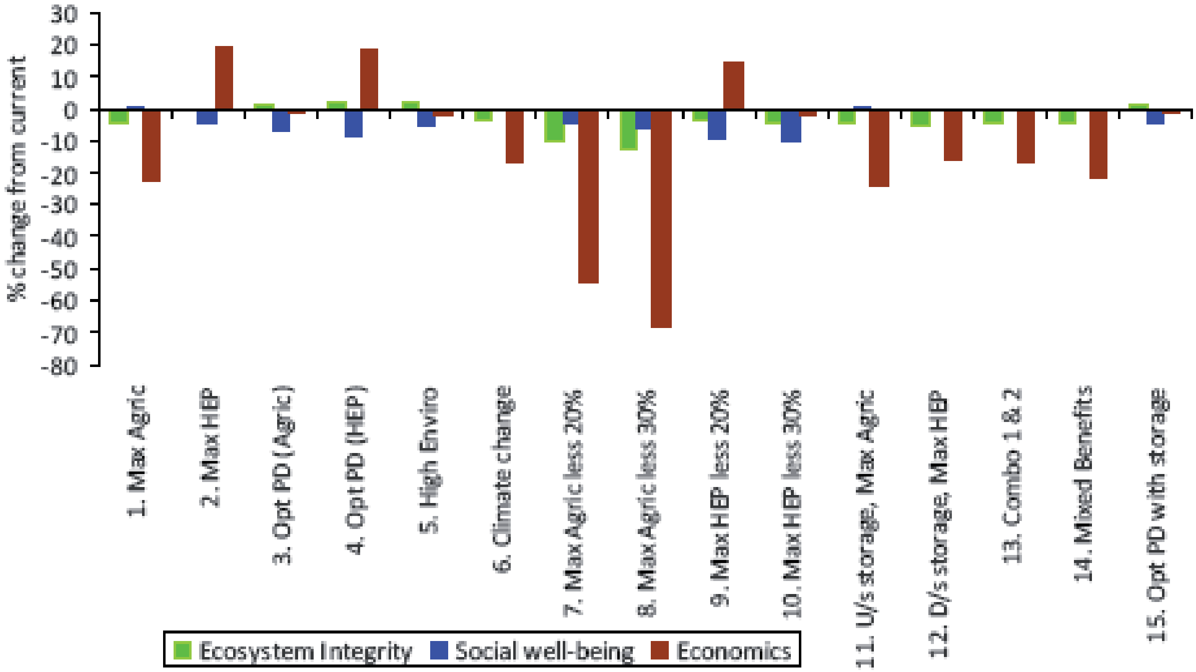


Figure 8.5 Percentage change from present day in terms of ecosystem integrity, social well-being and economic values.

The project conceded that one area that needs further attention is that of national level versus basin level tradeoffs – that is, between contribution to the national economy (and its need to alleviate poverty) and the welfare of people in the basin. This is a policy issue that was not addressed by the project as it is a political responsibility.

Section G: Implementation of environmental flows

According to the main Scenario report, once a scenario has been chosen as the optimal trade-off between development and resource protection, its flow regime becomes the environmental flow allocated for river maintenance. These flows are summarised for each of the scenarios in the DRIFT summary tables. The numbers provide an indication of the expected MAR for each scenario plus an indication of the annual distribution of flows in terms of:

- Volume of the wet-season lowflows;
- Volume of the dry-season lowflows (note there was an error in the main report where this line was identical to that above – this has been corrected here);
- Number of intra-annual floods;
- Number of extra annual floods.
- Lowflow duration curves
- Flood timing, magnitude and duration.

This information will be needed to implement the agreed flows.

Table 5.4 Hydrological summary data provided for a scenario (in this case MAX Agric) for operating the River FA Tool (example worksheet from *Summary Flow Change Data – Pangani.xls*).

MAXIMUM AGRICULTURE IN PANGANI BASIN								
	Site 1	Site 2	Site 3	Site 4	Site 6	Site 7	Site 8	Site 9
MAR	52.73	415.08	156.48	780.98463	688	30.4	115	1130.96
WSLF - Volumes (MCM)	16.57	268.58	71.17	463.31	265	7.25	39.19	506.47
DSLF - Volumes (MCM)	24.15	66.12	58.63	146.11 - periodic zero flows (c. 1:10)	418	10.63 - periods of no flow	42.24	480.81
Class 1 - Annual Frequency	4	1	0	2.5	0	6	1.68	0
Class 2 - Annual Frequency	2	2	0.58	2	0	4	7.42	1.5
Class 3 - Annual Frequency	1	4	1.74	2	0	1	3.79	3.26
Class 4 - Annual Frequency	1	3	3	3	0	0	2.26	1.42
1:2	P	P	P	P	A	P	Reduced - Use A	P
1:5	P	P	P	P	A	P	P	P
1:10	P	P	P	P	A	A	P	P
1:20	P	A	P	A?	A	A	P	P

The table above is extracted from the Pangani FA Tool User Manual and provides an indication of the flows that will need to be maintained in the river to achieve a particular scenario. This information is fed into the FA tool to predict the consequences to the ecosystem.

Implementation is just starting in the Pangani River. What will be necessary once a particular scenario has been chosen, is to investigate and plan for how this scenario would be achieved. This will include plans to regulate river flows from control structures (dams) and also to regulate activities associated with the river that are altering its condition.

Resource Quality Objectives (RQOs)

RQOs are measurable criteria to be used for monitoring the achievement of the implementation of environmental flows and may relate to the quality and quantity of water, the habitat and the biota. For example, the RQOs for a river site may be that the river should have x flow of y quality, that the river should remain sediment free and that the species composition of fish should be as in the natural state. RQOs have not been specifically defined in this project, but as the hydrological requirements to achieve a chosen scenario are available from the models (as shown above), so are the biological criteria available in the DRIFT model (or the Pangani FA Tool). Yet, these have not been structured or evaluated as suitable quality objectives to be used for monitoring of implementation. This may seem like a small issue, but when carefully considered the indicators suitable as objectives can differ substantially from all of the indicators which were used to determine the environmental flow. For example, if an indicator turns out to be insignificant in the achievement of environmental flows, then why monitor it as a RQO in the future? This can apply to a species (e.g. a fish which is not a good indicator of environmental flows need not be monitored) or a chemical constituent (e.g. salt may not change in relation to flows). By careful evaluation, it is possible to substantially reduce the cost of monitoring, which can make the difference between success or failure of the flow management system!

Summary of implementation initiatives described at a workshop to discuss EF in Tanzania (IUCN, 2010)

The Pangani Basin Water Officer (Mr. Hamza Sadiki) noted that it was a challenge to implement the 2002 National Water Policy requirement that makes provisions for the basins to take into account the environment as they allocate water. The environmental flow assessment was one of the components of the Pangani River Basin Management Project (PRBMP) – costing about USD 500,000. To implement this component (eflow assessment) a team was established and its capacity developed by Southern Waters (consultants). This team, with the technical assistance from the Southern Waters, has carried out the eflow assessment in Pangani basin.

Hamza noted that a hydrological model for the basin is now in place and that the basin has started using the information generated from the flow assessment in IWRM planning. In addition, the board is in the process of reviewing the scenarios that have been developed by the eflow team to select the appropriate ones to be adopted for allocating and managing water resources in the basin. The Basin is using information from the eflow assessment to create awareness among the stakeholders and already there is a broader understanding of costs and benefits of ensuring eflow in water allocation for the basin. Similar eflow assessments are now being carried out in other parts of the basin such as the Zigi Basin. The basin staff has had opportunities to present information generated from the Pangani eflow assessment at the national and global level.

The basin has a business plan and eflow assessment activities as well as water governance IWRM, climate change etc are embedded in the plan and are being implemented. In responding to a question whether there is capacity for eflow assessments, he noted that there is now sufficient capacity within and outside the basin to carry out eflow assessments in other parts of Tanzania. On responding to the question whether it would be more useful to have something more prescriptive or whether it will be a protracted process to agree on a particular scenario which is best for the basin, he noted that the scenarios will integrated into the IWRM plan which will be legally binding.

Section H: Monitoring issues

A great deal of data and information has been published in this project, which effectively provides a vital baseline against which future developments and monitoring can be compared. This is an ideal start to long-term implementation particularly if the costs of long-term monitoring can be curtailed by careful consideration of those indicators that are necessary to indicate performance of implementation (see Resource Quality Objectives above).

Section I: Successes, limitations and gaps

Overall this project has to be commended on being groundbreaking in its application. There are few projects which have approached the management of water resources in such a comprehensive way, dealing with environmental, social and economic issues in an integrated way. The project has surmounted limitations in the data available to produce an output that is of great value to resource managers and the people of Tanzania.

The project has adopted a challenging approach, making use of a modified DRIFT method that requires considerable understanding to be effective. The project team have taken this on with apparent enthusiasm and look to be set in taking this forward into implementation.

No matter how well a study is carried out, it is always possible to find limitations and gaps in the work done. This is not necessarily a weakness of those conducting the work, as often they are constrained by limited budgets, access to resources and even limited support from people who need to be involved. Thus, the purpose here is not to establish blame for limitations and gaps that may be apparent in the project, but rather to identify limitations and gaps so that they can be filled, for the sake of future implementation of environmental flows.

Gaps and limitations identified during this review, but which are by no means exhaustive and may have already been identified by the project Task 5 (PBWO/IUCN, 2008c), include:

1. Flow records and data were insufficient and of poor quality – future monitoring would add confidence to the outputs of the EF evaluation.
2. There would be value in refining the endorheic water flows as these are substantial.
3. The management of the hydrological data has been identified as an issue and suggestions have been made to streamline and make this more secure.
4. The standard DRIFT method (and most other EF models) requires that cross sections of the river sites are surveyed in order to understand the relationship between river channel form and flow discharge characteristics. This information forms the foundation of the understanding of environmental flow requirements by the various ecologists, yet this was not possible during the execution of this study.
5. Conceptual Models were developed that show how different species in the different zones of the Pangani River basin will respond to different flow regimes in different seasons (response curves were produced for indicator species). What is not indicated in the report, is how these curves are derived (given the lack of cross section surveys) and how confident the estimations are.
6. Because the Pangani River Basin Flow Assessment Initiative is largely concerned with how water allocation affects the livelihoods of people in the basin, this study only examines information from a direct consumptive use value of aquatic ecosystems to rural households. A broader economic perspective could add different views to allocation of water.
7. Missing from the Pangani river and estuary assessments is consideration of the importance of this ecosystem from a local and regional conservation/sustainability point of view. Most of the importance that has been attributed to the river has been through the use of short-term and local benefits.
8. The project conceded that one area that needs further attention is that of national level versus basin level tradeoffs – that is, between contribution to the national economy (and its need to alleviate poverty) and the welfare of people in the basin.
9. Implementation is not yet happening in the Pangani River – but is awaiting the conclusion of this project.
10. Resource Quality Objectives have not been considered in a format that would be useful for monitoring of implementation performance, however this type of information may only be developed as the project moves to implementation.
11. No information has yet been collected describing the overall cost of environmental flow assessment in this basin. Discussions revealed that this is a complex issue as the budgets used covered a wider range of subject matter than just environmental flows.
12. Missing from this package of reports, is a business plan for the PBWO to take environmental flows into implementation although this has apparently been developed but was not available.

Task 5 (PBWO/IUCN, 2008c) considers the gaps in this investigation in some detail. According to the schedule of work for the study, Task 5 task came after Task 1-4 (hydrology to socio-economic), and predated Tasks 6-10 (specialist studies to awareness creation). This task presented an opportunity to evaluate the gaps in the programme, to identify projects to fill these gaps, and then to move forwards (the evaluation was done in November 2006 although published in June 2008). Task 5 presented an excellent step in the planning phase, where there was sufficient latitude in the planning to be able to adapt the way forwards based on what was found in the early phases of the project. Yet, that this was the role of this report is not immediately obvious, possibly due to a somewhat misleading title. Maybe a sub-title of “planning the way forward” would have helped? Apparently this was primarily an awareness creation task – generating awareness amongst the project team members. The report also goes into considerable detail suggesting the type of data that needed to be collected, the way the models will be run etc. Again, this is an excellent approach that ensures that the final project will prove to be meaningful.

Possibly an overriding limitation of this project has been that the DRIFT model is a complex one. While it is supremely capable of gathering a wide array of information and transforming this into environmental flows and scenarios for consideration, the process to get there is complex and requires considerable and close involvement of personnel if they are to be effective at using but, more importantly, understanding the outputs.

Section J: Lessons learned and the way forward.

According to the Final Project Summary Report (PBWO/IUCN 2009) – *"because of the delays caused by attempting to obtain acceptable climate-change and other data, the project extended over several years with some large gaps between activities. Such a project loses momentum, risks losing both international and national team members, wastes time because old ground has to be re-covered when activities start again, extends even further than planned because of the difficulty of re-establishing timetables with project members now working elsewhere, and risks losing the interest of stakeholders such as the PBWO and its Board and Ministry. A sequence of shorter projects with well-defined end points would have been preferable* (not the view of this review though as short projects may have become disassociated whereas the present project is well structured).

The specialist studies (Task 6) were designed to fill major gaps in knowledge identified earlier in the project. The national team members did not do any of the studies, as these were all outsourced. Their results were, to various extents, more or less helpful in terms of the larger project goals. This may have been largely because they were done on very small budgets by teams who did not well understand the flows-assessment process or what data it required from them. In future similar projects it would be advantageous to choose national team members who would also take part in some way in any specialist studies, even if only as advisors.

One of the specialist studies was on the development of a national macro-economic tool for assessing the economic implications of the scenarios. This is usually done outside the flow assessment and linked in at a later stage. Such a plan was unsuccessful in producing what was needed and, again, including this as part of the flow assessment would have allowed the team members and the macro-economic specialist to better liaise and produce the required product.

A stakeholder workshop was held early in the project to assess stakeholder concerns (Scenario Selection Report; Table 1.3). Thereafter all discussions regarding the scenarios to be considered in the project were with the PBWO and its Board. Further consultation with a wider array of stakeholders might have revealed further scenarios of interest to the wider basin population.

The process following scenario production remains undeveloped. The PBWO has the opportunity to become a leader in how this work could proceed in terms of awareness raising; stakeholder consultation; a transparent political decision-making process; design and implementation of a basin water-resource management plan; and monitoring and adaptive management."

The Task 5 report (PBWO/IUCN 2008c) identified a number of priority projects designed to fill knowledge gaps in the project before the project was complete. A final priority list of eight projects was created and plans were made to take these forward, which they were to a greater or lesser degree. This report also introduced a number of ways of taking this work forward, which will not be discussed in detail here, other than to acknowledge the comprehensive approach taken.

This report (PBWO/IUCN 2008c) says in summary: "The tools and processes described in this chapter outline the way in which an FA approach supports sustainable development, through providing a comprehensive array of information on the costs as well as the benefits of any planned water management activity. The process should be an integral part of IWRM, with the ecological and social implications of development/rehabilitation given the same weight and attention as the economic and engineering aspects. We envisage the process being followed and the tools set up for each drainage basin, after which any scenario of interest can easily be investigated to show its costs and benefits. In a basin where the process has not been done, it should be started at the earliest stage of development/rehabilitation planning, so that the favoured scenario can be chosen BEFORE dam design or similar happens. Schemes should be designed to meet the flow and other requirements of the chosen scenario and not the other way round as presently happens in almost all parts of the world. This latter course has led to schemes being designed and built, and only afterwards do the detrimental costs of flow changes become apparent. The FA approach helps avoid this situation."

Chapter 3. The Wami River

Section A: Initiation and scope of studies

The project was carried out during 2007 and was led by the Wami River Basin Water Office (WRBWO) and a scientist from Florida International University. At the grassroots level, the project was coordinated by the Wami-Ruvu Basin Water Office in collaboration with the Tanzania Coastal Management Partneship (TCMP) and Florida International University. Financial support came from a partnership between USAID and the Coca Cola Company. The Wami IEFA formed part of the larger Tanzania Water and Development Alliance project. Staff from the Tanzanian Ministry of Water also participated.

It seems that the original concept of the project arose from a visit to the river by Michael McClain, Jeremiah Daffa and Jim Tobey, who provided the initial impetus for this project which was then taken up by the WRBWO.

The Wami River was chosen as a test case for the EFA process in Tanzania because of its national, environmental and socioeconomic importance, as well as its role in the projected future growth of the country. The Wami Initial Environmental Flow Assessment (Wami IEFA), was also recognized as a pioneering effort as a Tanzanian-led project and a proactive approach to management.

The overall objective of the Wami IEFA was to develop quantitative guidelines for management of flows in the Wami River Sub-Basin. Specifically, meeting this objective included the following tasks (Wami-Ruvu Basin Water Office (WRBWO). 2008):

- Review hydro-meteorological data for the Wami River Sub-Basin and fill gaps in the hydrologic record.
- Collect and synthesize existing information on hydraulics, geomorphology, ecology, and socioeconomic conditions in the Wami River Sub-Basin.
- Conduct targeted data collection at representative, strategically-identified sites in the Wami River Sub-Basin (and also in the estuary).
- Estimate the flow requirements at five selected sites, each located in a different part of the Wami River Sub-Basin.
- Develop guidelines for water allocation and flow management in the Wami River Sub-Basin.

Additional goals of the Wami IEFA were to form a strong team of Tanzanian experts that specialize in environmental flow assessment and to build the knowledge and capacity of the WRBWO staff by introducing them to new approaches and tools.

Objectives for an estuary study which was not part of the EF study and did not aim to determine the EF of the estuary (Anderson et al, 2007) were as follows:

1. Collect baseline ecological data on the estuary during the start of the wet season.
2. Identify valued ecosystem components of the estuary.
3. Describe threats to the estuary.
4. Make recommendations for future management and conservation actions.

The information generated as part of the Wami IEFA project (Wami-Ruvu Basin Water Office (WRBWO). 2008) was intended to provide decision-making support to the Wami-Ruvu Basin Water Office. The estimated environmental flow requirements were designed to give the basin water office a better sense of how much water can be allocated for extractive water uses while still maintaining a desired level of environmental protection for rivers and related ecosystems. It is acknowledged that while there is some uncertainty in these estimates for environmental flow requirements, these numbers are the most quantitative values currently available and are based on the professional judgment of some of the most capable scientists in Tanzania for making these types of recommendations. Further, the estimated environmental flow requirements should be refined and this tool adapted as more is learned about the Wami River Sub-Basin.

Section B: Process to define areas of study and assessment

Sites were selected using selection criteria adapted from the BBM site selection principles (King et al., 2000). Five optimally suitable study sites for ecology, hydraulics, channel morphology and socioeconomic activities were selected as representative sites for initial EFA studies in the Wami River basin. A reconnaissance report (EFA Team, 2007) provides a list of criteria for selection of sites. The sites were used to investigate the ecology, hydraulics, channel morphology and socio-economic activities.

Figure showing the zonation of rivers and estuary illustrating the location of sample sites.

Section C: Evaluation of the original & present state of the systems

River Hydrology

The objectives of the hydrological analysis related to the initial EFA in the Wami River basin (Valimba, 2007a, b) were broadly categorized into i) data collection and compilation, ii) data reconstruction and analysis and iii) estimation of data at ungauged EFA sites. Specifically, the objectives were to:

a. collect and compile river flow, rainfall and water abstraction data
c. reconstruct missing data points
e. analyze data to highlight seasonal variations and multi-year patterns of variability
g. provide accurate estimation of flows at ungauged EFA sites.

According to available compiled information on river gauging observations, there have over time been 26 gauging sites in the basin (reference needed). The spatial distribution of these river flow gauges indicates that most of the rivers have been measured at some point, although not for the same time periods. Only a few gauging stations were operational at the time of the project commencement, so consequently available flow data were patchy and did not cover the same time periods at all sites.

According to the hydrology report (Valimba, 2007a), because of the patchiness of the data, the rating curves at various gauging stations needed revision before they could be used to estimate discharge from available water levels. Therefore, no attempts were made to use available water levels to determine discharge.

The hydrology report (Valimba, 2007a) was very detailed and appears comprehensive. It had to deal with a lot of missing data due to inoperable weirs and documented the hydrology, abstractions as well as rainfall.

River Water Quality

In terms of water quality, some data is available from selected sites and housed at the WRBWO; however, very little is known about how physicochemical conditions vary spatially and temporally in the sub-basin (Wami-Ruvu Basin Water Office (WRBWO). 2008). On-site water quality was used where possible during the EF determination. In the summary report there were inferences about pollution coming from the socio-economic study where the presence of polluting industries and agriculture were noted. Effluent from the Mtibwa Sugar Factory and Dakawa Rice Project further upstream in the watershed was identified as a source in declining water quality in the Wami River (Gritzner, 2007).

River Habitat

Information describing the geomorphological nature of the sites was collected and well described for the sites and the overall catchment (Mwanukuzi, 2007) but not in any quantitative way. The project used the approach of Rowntree and Wadeson (1999) to divide the river into geomorphic zones, and presents a largely narrative geomorphological description of the river sites, sediment and the channel morphology. Clearly the passage of sediment through the sites was an issue of uncertainty.

The hydraulic characterization also provided a part of the site habitat description (see below). There was however, no specific attempt to characterize the overall habitat as would be suitable for the biota at the site and which thus forms an integral part of the site description.

Hydraulic habitat

Very comprehensive reports were produced that describe the hydraulics in greater detail than is immediately necessary for this assignment (Ndomba, 2007a, b), possibly as there was a lack of existing information and existing rating curves were erroneous and needed revision. Nevertheless, this information is important in the longer term, and if the Environmental Flows have precipitated a resurgence of hydrological monitoring, then this will prove to be beneficial in the long run.

The hydraulic data collected included cross section geometry data, reach lengths, water levels, stream flow discharge, velocity and roughness conditions.

River Biota

Overall the collection of fish and invertebrates was done according to classical approaches which provide considerable information (Tamatamah, 2007b), but the study did not take cognisance of recent advances in rapid biomonitoring techniques which may have made the process simpler. Accordingly, although there was collection of biota, and some analysis of species diversity, there was little interpretation of the state of this biota compared to the natural condition (although such a comparison would have been constrained by a lack of historical data). In terms of the environmental requirements of the biota, there was little information for invertebrates other than a record of the pollution tolerance of the invertebrates. For the fish there was consideration of the flow requirements according to species guilds which provided valuable information for assessing the EFR.

The invertebrates were collected with a Surber sampler and identified to family level. The method notes that collection was done on the substrate which was stirred with a stick, but there is no indication whether there was a range of biotopes surveyed at each site.   Diversity of taxa was determined using the Shannon-Weaner diversity index which was calculated together with the Species Evenness. Taxa were further divided into three arbitrary groups based on their sensitivity or tolerance to pollution making use of the reference “Aquatic Invertebrates of South African Rivers Field Guide by Gerber and Gabriel (2002)”. Taxa were analysed according to these three groupings and those sites with significant presence of pollution tolerant families were identified. There was no indication how this data was used to determine the flow requirements. A total of 11,777 specimens were collected and identified from the 5 sites – which represents a significant labour and provides good baseline information for the future, but may not have been warranted.

Fish were collected using gill and seine nets. Netting was complicated by the presence of large objects including crocodile and hippo. Specimens were identified to species level and the statistics of each collected.

A number of computational techniques were applied to the catch obtained to provide information on the relative abundance and distribution of fish species. Techniques included catch per unit effort (CPUE), fish biomass (g/m^2) and the Shannon-Weaner diversity index. Differences in fish biomass, catch per unit effort (CPUE) and species diversity among sampling sites were assessed using analysis of variance (ANOVA) followed by the least significance difference (LSD) test. A total of 37 species have been recorded in this river – with 28 recorded during the site survey.

In order to interpret the flow requirements, the guild concept was applied to cluster species with similar ecological requirements. This included consideration of their flow requirements and water quality such as low-oxygen tolerance.

Vegetation – a total of five sampling sites each with five plots, making a total of 25 sampling plots, were surveyed. Plots measuring 500 m^2 were used for sampling of trees and 10 m^2 plots for juvenile trees and shrubs. Plots measuring 1 m^2 were used to study herbaceous layers and grasses in the riparian zone. Moreover, the qualitative approach was used in areas where a standard quantitative approach could not be employed due to the complexity of landscape in the site and level of disturbance in the riparian zone. Sampling of trees was done on 20x25m quadrats.

A report on the vegetation ecology component of the EFA (Mligo, 2007) was compiled. In the report there is documentation of the flow dependent riparian species, but in a simple way – the association of species with water. There is no indication of the requirement for flooding etc. There is a great deal of discussion about the human impacts on the riparian zone but less on the flow requirements. Besides species lists, the only data was a comparison of the species density and diversity. This is not that helpful in terms of establishment of the environmental flow requirements.

The tables below give an example of how the state of the ecosystem is interpreted for management purposes. The table above is the summary of all five sites. The information in this table was taken from five separate tables, one for each site, with detailed information about all the components analyzed for each site. The table below is an example of one of those tables for the site Wami at Mtibwa. These tables were created during the flow recommendations workshop in December 2007.

River Socio-Economic Situation

A detailed socio-economic report was undertaken (Hyera, 2007a), describing the use of natural resources in the basin. There was however little linkage between these activities and the actual quantification of the water requirements although the linkage is acknowledged. The report did however state that the fish population in the Wami River is no longer adequate to support local communities in the basin and detail on this was provided. As a result, communities are forced to find other sources of food. The Matipwili villagers, for example, have begun to cultivate within the Wami River flood plain to augment their diet.

Stakeholder consultation appears to have yielded excellent information related to diverse subjects including the salinity of the water and the fish catch.

Table 4.1. Summary of experts' determinations of environmental management class for five sites in the Wami River Sub-Basin.

B = Management initiatives should **maintain or restore system to be largely natural with few modifications**. A small change in natural habitats and biota may have already taken place, or may take place in the future, but most or all ecosystem functions should be essentially unchanged.

C= Management initiatives should **maintain or restore system to be moderately modified**. A loss and change of natural habitat and biota may have already taken place, or may be permitted to occur in the future. Basic ecosystem functions should be predominantly unchanged.

Wami IEFA study sites	Present environmental state	Trajectory of change	Sensitivity and importance	Recommended EMC	Recommended Actions
SITE 1: Kinyasungwe River at Kongwa (1GD16)	C/D	-	Medium	C	Maintain
SITE 2: Mkondoa River at Kilosa (1GD2)	B/C	-/0	Medium / high	B	Maintain/Restore
SITE 3: Wami River at Mtibwa (no gauge)	B/C	-	Medium / high	B	Maintain/Restore
SITE 4: Wami River at Mandera (1G2)	B	-/0	High	B	Maintain
SITE 5: Wami River at Matipwili (new gauge)	C	-	Medium / high	B	Restore

SITE 3: Wami River downstream of Mtibwa (no gauge)					
Component	Present State (A-F)	Trajectory	Importance or sensitivity	Recommended EMC (A-D)	Comments
Hydrology	C	-	High	B/C	Some water abstractions for agriculture and community water supply; increasing abstractions are likely; site is within the swamps
Fish	B	-	medium	B	Suspected poor water quality and water abstraction. 6 species caught.
Invertebrates	B	-	medium	B	None of sensitive species caught here; some species moderately tolerant. Expansion of sugar farm's irrigation will change habitat quality and quantity.
Riparian veg	C	+	High	C	Loss of natural vegetation in the flood plan due to sugar and rice farming. 5 sensitive species found.
Geomorphology / Hydraulics	B	0	Medium	B	Low energy system; largely natural with few modifications from garbion built upstream. Some sensitivity because change of flow would affect deposition patterns
Local perceptions	B	0	High	B	People have problem with flooding; perception of poor water quality from sugar plantation; perceptions of trajectory are mixed.
OVERALL	B/C	-	Medium/high	B	

Estuary Ecological Information

This was reported in Anderson et al, (2007) but was not intended to be an EF report. A preliminary assessment of the present state of the estuary was presented following a single survey.

Estuary Water quality

For the estuary water quality assessment salinity, temperature, conductivity, pH, dissolved oxygen, turbidity and sediment character was collected. This survey, especially the water quality, being based on a single visit, cannot properly represent the situation of the estuary, but does represent a start in the process of understanding.

Estuary Biota

This survey focused on fish (and the social interactions), but also considered other aspects at the level of a rapid ecological assessment. Riparian vegetation, mammals and birds were also identified. It was noted that a decline in the quantity and quality of freshwater delivered to the estuary could be having an impact on the fisheries – with improper catchment the greatest threat. Increases in suspended sediments and nutrient concentrations are probable consequences of agricultural expansion in the basin.

Section D: Evaluating the importance and sensitivity of the systems

This is provided in statements of a general nature (Wami-Ruvu Basin Water Office (WRBWO). 2008) such as *"The Wami River Sub-Basin is one of the most important river systems in Tanzania, draining a centrally-located area of >40,000 km^2. With its headwaters in the Eastern Arc Mountains and its estuary within the newly created Saadani National Park, the Wami Sub-Basin harbors important terrestrial and aquatic ecosystems. The lives and livelihoods of human residents of the region are also intimately linked to freshwater resources."*

During the actual environmental flow determination process, there was a process to capture the importance and sensitivity of the ecosystem at each site. Each results table for each site has a column which shows the present state of the ecosystem as well as its Ecological Importance and Sensitivity as well as trajectory of change. Apparently this was assessed by expert judgment during the workshop process. This information was then used to identify the recommended management class and objectives for restoration or maintenance of each site including recommendations for flow management.

Section E: Quantifying the relationship between river flow and the ecosystem

The hydraulics component in this study provided the baseline for interpretation of the relationship between the river flow and provision of habitat appropriate for the various biota. This was done by mapping riverine habitats and evaluating the temporal dynamics of habitat disappearance over the course of hydrological year with the help of a hydraulic model PHABSIM. The model calibration was achieved by matching the simulated and observed water surface elevation and velocities.

Guidance from several methodologies for conducting EFAs was used, including the Building Block Methodology (King et al. 1998); DRIFT (King et al. 2003); Ecological Limits of Hydrologic Alteration (Poff et al., unpublished); and possibly most significantly the 'Savannah Method' (Richter et al. 2006). During the scoping phase of the Wami IEFA it was determined by project leaders that none of these methodologies were feasible in their entirety, but that they each contained ideas and tools that could be useful to the Wami initiative. Thus, the approach employed in the Wami IEFA represented an adaptation of select parts of these established EFA methodologies to the local context.

Essentially the process followed was:

- Initiate the project, review and capacity building
- Gather all existing information about the present state of the system including social and ecological aspects
- Reconnaissance of the river, selection of river reaches and determination of scope.
- Conduct survey of sites to determine the dependence of the ecosystem on water flows.
- Definition of initial environmental flow recommendation and determine management class.
- Dissemination of results

Each of the components had to be assessed in terms of its flow requirements. Biota are often considered the best indicators as they occur at the "end of the line" and thus integrate all the conditions that are required to sustain them. It is useful to consider how the fish and invertebrates were considered as an illustration of the approach used. This can be summarized as follows (Tamatamah, 2007b):

1. *Review of literature on ecology and flow-related information on fish (and invertebrates) species in the Wami River.*

   The literature review involved compilation of a data set summarizing all information available on environmental and social aspects related to water resources management in the Wami River sub-Basin. This included information on fishes and macroinvertebrates, including species distributions, the habitat preferences and water quality tolerances of keynote species or developmental stage, patterns of movement, migration and passage requirements, diet composition and foraging behaviour, reproductive biology, spawning habitats and larval/juvenile requirements were compiled.

2. *Selection of study sites to characterize river reaches likely to be affected by existing and future water resource developments*

3. *Field survey at each site to collect data on environmental and social parameters (e.g., fish and macroinvertebrate species composition, abundance and habitat use; human uses of river resources) in relation to flow conditions*

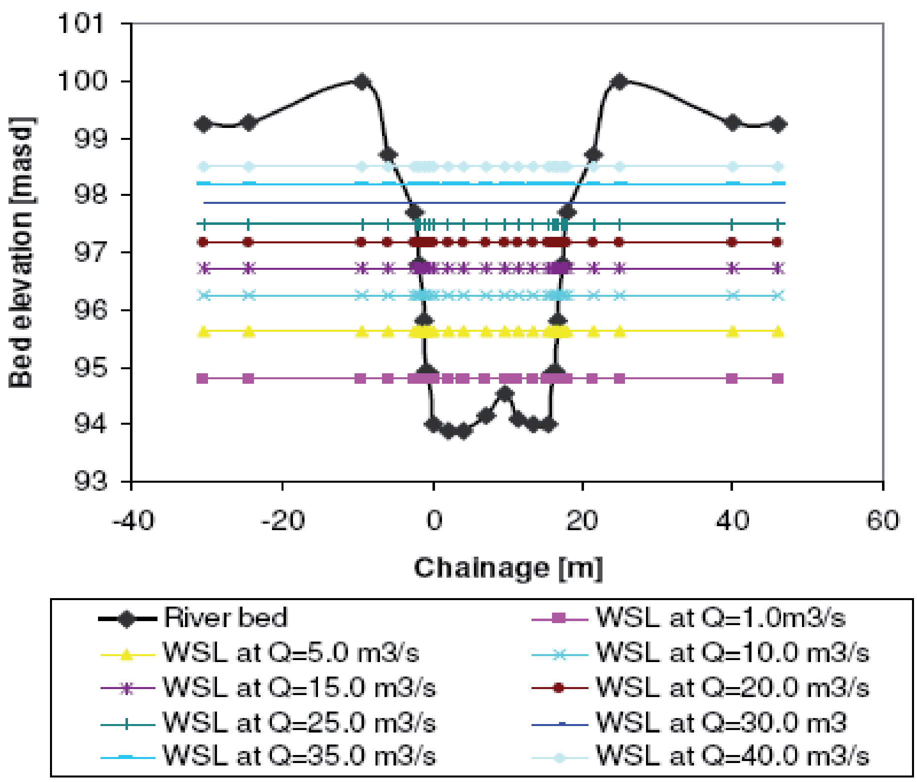
   A 5-day field survey was conducted once during the month of November 2007, coinciding with the dry season in the Wami River sub-basin. Examples of the data collected for the ecological component were fish species composition, abundance and habitat use of each species in relation to the flow. The range of meso- and microhabitats present, including riffles and pools at selected transects at each of the five study sites were sampled by the hydraulic engineer and geomorphologist. Site data on other stream habitat characteristics, such as width, depth, velocity, substrate characteristics, instream cover and bank cover, riparian vegetation, and selected physio-chemical water quality parameters, were obtained from relevant specialists working in the EFA team.

Each of the experts (Aquatic ecologist, hydrologist, hydraulic engineer, geomorphologist, social scientist) conducted a thorough background review of all available information on the Wami River Basin as related to their particular area of expertise. This information was summarized in a project report / literature review on each area of study. Following the literature review, the entire team met again for a workshop to identify the guidelines for the next phase of the study, and to select a preliminary list of sites where field data would be collected. This workshop lasted 3 days. This was followed by detailed surveys by each specialist as well as with meetings with local communities. An intention here was that the whole team went into the field together in order to develop an integrated perspective on the project (Anderson *pers com*.)

During December 2007, following desktop research and field surveys, an experts' workshop was held where the Wami project team collaboratively worked to estimate environmental flow requirements. Following presentation and synthesis of all data known and available for the Wami River Sub- Basin, the team went through several exercises to identify management options and then quantified flow needs for five sites (Wami-Ruvu Basin Water Office (WRBWO). 2008).

The general approach of the Building Block Methodology (BBM) approach was adopted to identify management classes and goals (King et al. 1998). Each of the experts was first asked to identify the present environmental state at each of the five sites in relation to the reference condition. Experts were asked to categorize the site as A (natural, unmodified); B (largely natural with few modifications); C (moderately modified); or D (largely modified). The establishment of these classes helped to guide the subsequent process of determining environmental water allocations.

To estimate environmental flow requirements for each of the five sites, a combination of professional judgment and quantitative information on flow needs for different riverine processes or biota was used (Wami-Ruvu Basin Water Office (WRBWO). 2008). This process drew upon guidelines from methodologies like the Building Block Methodology and the Savannah River method (King et al. 1998; Richter et al. 2006). Experts were asked to identify the minimum hydraulic requirements (in terms of depth, velocity, wetted perimeter, or water level) necessary to ensure survival of biota or to facilitate key geomorphologic processes. The hydraulic engineer then used field data from channel cross-sections and modeling techniques to approximate discharge for each of the hydraulic conditions identified by the experts. The social scientist was simultaneously asked to quantify the amount of water necessary to fulfill basic needs for local human populations. As a team, all environmental flow recommendations were discussed and the hydrologist provided information as to the availability of flows during different seasons and different years, based on previous analysis of the hydrologic record (Wami-Ruvu Basin Water Office (WRBWO). 2008). It is significant in the above, that the specialists produced a recommended management class, which is a departure from some of the other approaches where it is felt that only stakeholders could set a management class.



Simulation results of Water Surface Level measurement (WSLs) at various floes (Q)

The figure above illustrates the cross sectional survey of the river as associated with various water quantities (flows).

Below is a tabulated example of the eventual flow requirements for a site on the Wami.

Table 4.2.5 Recommended environmental flows for Wami River at Matipwili

	WAMI AT MATIPWILI								
	Driest year			Maintenance year			Wettest year		
	Recom.	Available	Recom. Inst Peak	Recom.	Available	Recom. Inst Peak	Recom.	Available	Recom. Inst Peak
Oct	4.6	4.6		6.6	13.9		37.0	68.3	
Nov	5.5	6.2		6.6	27.3		37.0	279.1	
Dec	8.3	16.7		14.7	57.3		86.5	529.1	
Jan	5.3	10.6		22.8	69.0		136.0	433.5	
Feb	6.4	12.9		30.9	51.6		185.5	341.4	
Mar	5.9	5.9		39.0	73.4		235.0	490.0	
Apr	21.2	107.2	37 (T = < 1 yr)	39.0	202.5	39 (T = < 1 yr)	235.0	1302.5	220 (T = 1.5 yrs)
May	21.2	274.8		39.0	152.7		235.0	489.2	
Jun	16.0	44.7		28.2	52.4		169.0	192.0	
Jul	10.7	29.3		17.4	29.1		103.0	63.3	
Aug	5.5	16.2		6.6	22.2		37.0	53.9	
Sep	5.5	11.0		6.6	16.3		37.0	64.6	

Section F: Setting a vision for the river and development of scenarios

Vision for the basin

Many environmental flow processes do not clearly document the vision for the river, presenting either a vague statement about its importance or alternately providing a "science biased" vision produced by the project team. Ideally this process should be a stakeholder process. In this case however, the Wami/Ruvu Basin Water Office has provided a clear Vision statement (see below). This type of vision provides an excellent start to the management of the water resource.

Table 1.1. The Wami/Ruvu Basin Water Office: Vision, Mission, Core Values, and Main Responsibilities

Vision: Basin water resources sustainably managed for the socio-economic and environmental needs, interests and priorities of the basin population.
Mission: To facilitate integrated water resources management efficiently and effectively in order to address the resource needs, interests and priorities of the Basin population while protecting and conserving the water resources.
Core values of the WRBWO reflect a strong commitment to: • Equitable and fair allocation of water that is socially desirable, economically viable and environmentally sustainable. • Transparent and accountable service provision to all people in the Wami/Ruvu Basin. • Promotion of integrated water resources management (IWRM) in the basin. • Efficient and effective delivery of quality services to basin stakeholders. • Being responsive to the basin stakeholders' needs and queries.
Main responsibilities of the WRBWO: • To issue water use permits • To monitor and regulate water use according to natural availability • To control and take legal measures against water resource polluters • To resolve water use conflicts • To collect different water user fees and use them for office operation • To sensitize stakeholders on the sustainable use of water resources • To facilitate the formation of Water User Entities. • To facilitate the formation of catchment/sub-catchment committees • To conduct operation and maintenance of water resource monitoring stations • To assess and monitor the quantity and quality of water in the basin • To coordinate the Integrated Water Resources Management plans • To participate in water resources protection programs

According to the Wami reports, maintaining the ecological integrity of the Wami River Estuary is of important national interest to Tanzania and local interest to Saadani and other coastal villages, not only from an environmental conservation perspective but also on the basis of the important goods and services that the intact estuarine ecosystem provides (Anderson et al 2007). Emerging threats to the estuary include human population growth, increasing importance of Saadani National Park, mangrove cutting, fisheries, and land use change and increasing water withdrawals in upstream areas.

The social surveys conducted by the social scientist member of the Wami IEFA project team revealed the views of the general population on the state of the resource (Hyera, 2007a). During discussions, villagers expressed their feelings about the existing situation. The majority of respondents were not happy about declining benefits from the river resources. The major concern was on increased poverty, since their lives largely depend on river resources. In this respect, the desired situation of the river as outlined by villagers include: availability of water throughout the year, availability of fish in all seasons, availability of plant species for medicine, vegetables, and raw materials for baskets and mat making. They also desired available flood plains for cultivation. This type of information again provides an excellent start to integration of a vision for the basin with management objectives.

Table 8: The desired state

River resource	Desired state of the river
Water	➢ Availability of clean water for domestic use throughout the year ➢ Availability of water for livestock ➢ Availability of irrigation during dry seasons ➢ Availability of water for fish and other species depending on the river for habitat ➢ Availability of water (deep pools) to allow children to swim.
Fish	➢ Increased type of fish species as in past decades ➢ Availability of fish during dry season
Vegetation	➢ Availability of medicinal plants throughout the year ➢ Available tree for timber, poles and fuel wood and boat making
Wildlife	➢ Available wildlife for food
Soil and stones	➢ Available soil and stones for building
River ecosystem	➢ Available wet flood plain for cultivation

Scenarios for the basin

The Wami investigation did not become involved in the development of scenarios but has laid the foundation through the development of a vision for the basin as outlined above.

Section G: Implementation of environmental flows.

As described by the final project report, (Wami-Ruvu Basin Water Office (WRBWO). 2008) the information generated by the Wami IEFA project is intended to provide decision-making support to the Wami-Ruvu Basin Water Office. The estimated environmental flow requirements for the five sites are designed to give the basin water office a better sense of how much water can be allocated for extractive water uses while still maintaining a desired level of environmental protection for rivers and related ecosystems.

The figure below is an example that represents the outcomes of the flow assessment in terms of the amount of water that needs to be allocated to the environment (the EF allocation) together with the amount of water that is available for other users.

While implementation of this is in its infancy, already there has been productive use of this information (Anderson *pers com*). The WRBWO have used the information from the Wami IEFA, particularly the flow recommendations, during negotiations for water concessions on several occasions.

Resource Quality Objectives

The use of Resource Quality Objectives has emerged as an important part of monitoring and implementation of resource management. Some background and guidelines on this are presented in Chapter 6 Section H. These have not been specifically determined for the Wami.

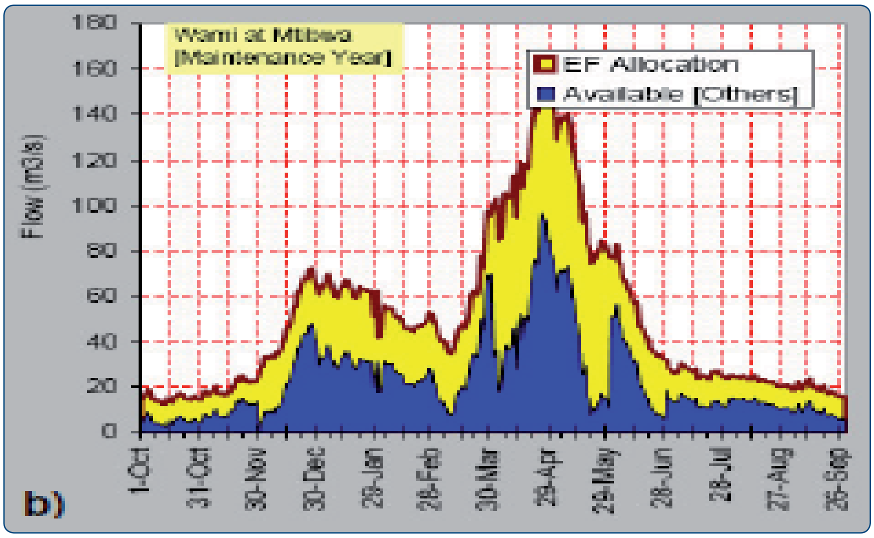


Figure illustrating the presentation of the EF in comparison to the total river flow

Summary of implementation initiatives described at a workshop to discuss EF in Tanzania (IUCN, 2010)

The acting Wami-Ruvu Basin Water Officer (Mr. Florence Mahay) noted that one of the most pressing needs was to carry out eflow assessment for the basin. The Wami River Initial Environmental Flow Assessment (EFA) project was a component of the Water and Development Alliance Program supported by USAID and Coca-Cola Company. The program was implemented in partnership with the Kwanza and Bonite Coca-Cola bottlers, World Vision, the Tanzania Health, Environment and Sanitation Association (THESA), the Coastal Resources Center at the University of Rhode Island, Florida International University (GLOWS program), the Wami Ruvu Basin Water Office and The Ministry of Water.

However, funds were limited, so the basin with a variety of researchers carried out the eflow assessment for a period of only 8 months. One of the biggest challenge was availability of data and information especially baseline information. Some of the outputs were: a list of detailed suggested studies to be carried out and a prescriptive indication of the eflow. There was no consideration of scenarios and water quality aspects. The Basin used the information generated from this study to make some water allocation decisions.

To implement the recommendation of the previous eflow study there is a new initiative being supported by Integrated Water, Sanitation and Hygiene (iWASH) programme which will carry out a detailed eflow assessment. Various questions were raised by the moderators to the basin water officer who subsequently responded to them: At any of the sites, was there too much water been taken out (over allocated)? Yes, there has been from some of tributaries. Was the information on eflows useful and is the basin using it for implementation? This was a very limited study and the process had not established a link between hydrology and ecology for example. What is the entry point for the EFA, is the demand for EFA coming from the managers of the resource or outsiders and/or international organizations, does it matter to carry out an EFA? In the case of Wami-Ruvu, EFA was our priority and decision came from basin. This is also supported by the policy and legal framework of Tanzania. Does EFA have a start and a finish time line? There is a need to make a start and decide what types of flows are needed for the future. But the Basin needs to continuously monitor and make adjustments accordingly, so it is an ongoing process

Section H: Monitoring issues

Some follow-up work was done in 2008-2009 to develop better GIS information for the Wami Basin, and to train WRBWO staff on use of GIS (Anderson *pers com*). The WRBWO has also continued to collect information. In 2009, a wet-season sampling event was planned but then had to be postponed. Starting in mid-2010, a new sampling campaign and effort to refine the flow recommendations for the Wami is beginning. The project will expand to include the Ruvu sub-Basin as well. The financial, technical, and political support for that project has already been secured (Anderson, *pers com*). Nevertheless, no formal monitoring programme was available for this review.

Section I: Successes, limitations and gaps.

Appendix 2 of the Final Report (Wami-Ruvu Basin Water Office (WRBWO). 2008) presented a useful compilation of the data uncertainties and research priorities. This presentation took the following form:

Wami River Initial EFA—Data uncertainties and research priorities
SITE 2: Mkondoa at Kilosa

Component	Uncertainty or data limitation
Hydraulics	• Hydraulic controls not pronounced, so sandbar was used in modeling. • The effect of bridges downstream as hydraulic controls has not been simulated. • Only one discharge at low flow conditions was used for calibration of hydraulic model.
Geomorphology	• Flow measurement during the wet season • Rate of sedimentation is unknown. • Controls on human development; lots of rain-fed agriculture upstream
Fish	• No reference fish list with which to guide more species-specific flow recommendations • Very few species (only 2) caught during field survey • No water quality data to relate to fish physicochemical requirements in recommending flow.
Invertebrates	
Riparian vegetation	• Data was sufficient enough to represent co-existing communities in the riparian ecosystem. • Most sensitive species were highly represented (*P. mauritania*, *Typha capensis*, *A. filiculoides*, *M. pigra*, *P. purpureum)* • The type of disturbance was due to banana farming and sugarcane. • It can be anticipated that the tradition of the people around the area is in accordance with management of riparian vegetation.

Component	Data collection and research priorities
Hydraulics	• Low, medium and high flow discharges should be sampled to mimic seasonality.
Geomorphology	• Study the rate of sedimentation. • Sediment delivery downstream. • Sediment characteristics during peak flows and impact of peak flows on river channel.
Fish	• Water quality data needs to be collected • Fish sampling in the wet season to capture those which were missed in the dry season.
Invertebrates	
Riparian vegetation	• Upstream and downstream information is still necessary for comparison purpose and to assess the possible maximum and minimum level of disturbance.

This project has, with a relatively small budget, achieved a great deal that can be productively used for the management of resources in the Wami River. Coming from a data and information poor background, and limited in its scope to undertake field surveys, the project has used the information available to good effect to produce flow requirements for each of the sites selected on the Wami. If it is acknowledged that these EF assessments have a low confidence, and if the basin authorities are amenable to an adaptive management approach, then this information can be used effectively for the allocation of water. However it is important to stress that an adaptive approach would need to be followed if contrary management is to be avoided.

The method of determination was also appropriate for the system as it was amenable to the data poor situation and relied on expert judgment.

General limitations could be summarized as follows:

- The 8-month timeframe for planning, executing and completing the project was extremely tight; an initiative of this size normally would call for at least a year timeline. With a budget of approximately US$45,000 for consultants' fees, field activities, and workshop costs, the funding available for this project placed restrictions on the work that could be accomplished; environmental flow assessments typically cost a minimum of US$100,000 and can be upwards of US$1,000,000.
- A larger budget would have allowed for the hire of more experts and more field data collection, including a wet-season sampling event.
- The limited information currently available for the Wami River Sub-Basin presented another substantial challenge, and means that scientific uncertainty is inherent in the results and conclusions of the project.
- Staffing of the project was an issue as all team members had a full list of other responsibilities.

- Data limitations presented a considerable challenge to the Wami IEFA project, requiring experts to use their best professional judgment.
- Very few scientific studies have been completed in the Wami River Sub-Basin.
- In terms of hydrology, a concern is the quantity and quality of data available for the Wami.
- In terms of water quality, data are available from selected sites and housed at the WRBWO; however, very little is known about how physicochemical conditions vary spatially and temporally in the sub-basin.
- The hydraulic survey was carried out in the dry season but there is a need for a wet season survey.
- Many of the weirs were inaccurate and required re-calibration.
- Information describing the nature of the habitats at the sites was collected but not in any quantitative way.
- The report presents a largely narrative geomorphological description of the river sites that document the sediment and the channel morphology. Clearly the passage of sediment through the sites was an issue of uncertainty
- Scientific studies have not specifically focused on the flow needs of aquatic biota in the Wami.
- The ecological importance and sensitivity of the river - this is only provided in statements of a general nature although there is a column in the results tables for each site, which show the present state of the ecosystem as well as its Ecological Importance and Sensitivity. This was assessed in a workshop situation using expert judgment. A more rigorous process would be useful in the future.
- Much of the information available on species records for fishes and other aquatic biota, and their distribution in the Wami Sub-Basin is qualitative and anecdotal.
- Overall the collection of fish and invertebrates was done according to classical approaches. Although there was collection of species, and some analysis of species diversity, there was little interpretation of the state of this biota compared to the natural condition. In terms of the environmental requirements of the biota, there was little information for invertebrates other than a record of the pollution tolerance of the invertebrates done at a relatively coarse level. For the fish there was consideration of the flow requirements according to species guilds which provided valuable information for assessing the EFR.
- There was no indication whether there was a range of invertebrate biotopes surveyed at each site.
- There is no indication in the vegetation report how the flow requirements were ascertained.
- Estuary – the project carried out provided an initial overview of environmental conditions in the estuary, but only for the time of the year when the information was collected. This project was not part of the Wami EF assessment although it provided useful data. In the future, an EF assessment of the estuary will be necessary as it may have a flow requirement which is different to the river and may thus influence the EF of the river.
- No scenarios have been developed or considered although visioning has been done for the basin as a whole.
- Resource Quality Objectives have not been set and will need to be if there are to be objectives against which monitoring can be based.

Chapter 4. Great Ruaha River

Section A: Initiation and scope of studies

Because of its importance to the national economy, the Rufiji Basin was selected as one of three in which the new policy and basic concepts would be pilot tested (The other two were the Pangani River and Lake Victoria Basin). The Ministry of Water and Livestock Development (MWLD) established the Rufiji Basin Water Office (RBWO) in 1993, with the mandate to oversee all matters concerning the development, management and regulation of water resources in the basin. This office thus took responsibility for the EF assessment.

Key work has been summarized in a number of publications in international media. Notable have been papers by Kashaigili et al, (2005, 2006, 2007, 2009) and WWF-TCO (2010). They draw on information produced by the Project RIPARWIN (Raising Irrigation Productivity and Releasing Water for Intersectoral Needs), funded by DFID-KAR (Knowledge and Research) and managed by Sokoine University of Agriculture, Tanzania; Overseas Development Group (ODG) of the University of East Anglia, UK; and the International Water Management Institute (IWMI-South Africa Office). A number of other studies have been carried out on the Great Ruaha River and on the associated Usangu Wetlands, many of which contribute to the aims of understanding the environmental flow requirements of the system. They were nevertheless not specifically coordinated as such which probably reduces their overall impact. The most recently added project contribution has been published by the WWF (WWF Tanzania Country Office (WWF-TCO). 2010). This report was only finalized after this review had been drafted but because of its importance, information from this study has been included where possible. This project was funded by the EU through the office of the WWF and forms a part of their project entitled "Integrated Water Resource Management in the Great Ruaha River Catchment, Tanzania". The major issue to be dealt with was the need to reinstate the dry season flows in the reaches of the river through the Ruaha National Park (RNP).

In 2007 WWF, using a grant from the EU, began to work with stakeholders in Tanzania to decide on the objectives and methodology for conducting an EFA in the GRR. A team of International and Tanzanian specialists were commissioned for this work, including a geomorphologist, hydrologist, hydraulic engineer, fish and macroinvertebrate biologist, and vegetation ecologist.

The objectives of the WWF study (WWF Tanzania Country Office (WWF-TCO). 2010) were to:

1. recommend flow rates, for different seasonal scenarios, required to restore dry season flows to the middle section of the GRR and Usangu wetland in the Ruaha National Park (RNP); and

2. identify a range of options to support implementation of environmental flows, providing a short-list of preferred options, identified against agreed criteria, in consultation with a wide range of stakeholders at local and national levels in Tanzania, and

3. determine the required inflows into the eastern Usangu wetland, in order to meet the recommended flow rates, downstream, in the RNP; as well as to determine the response of the wetland to changing flow regimes, not only those caused by upstream abstraction, but also with respect to proposed engineering modifications, i.e. the construction of the Lugoda Dam, and the Ndembera transfer option.

These objectives were extremely broad and encompassed several aspects of the problem related to the amount of water to be had in the river and wetland, and in this, the objectives were commendable.

The focus of the river component of the 2010 EFA study was the section of the GRR between the wetland outlet at Ng'iriama and the inlet to Mtera Dam, 211 km downstream. This section of river is referred to throughout this document as the middle GRR (MGRR). The reason for focusing the study on the MGRR was that this is the section of the river in which the low season flows have ceased since 1993, because of abstractions and catchment modifications upstream.

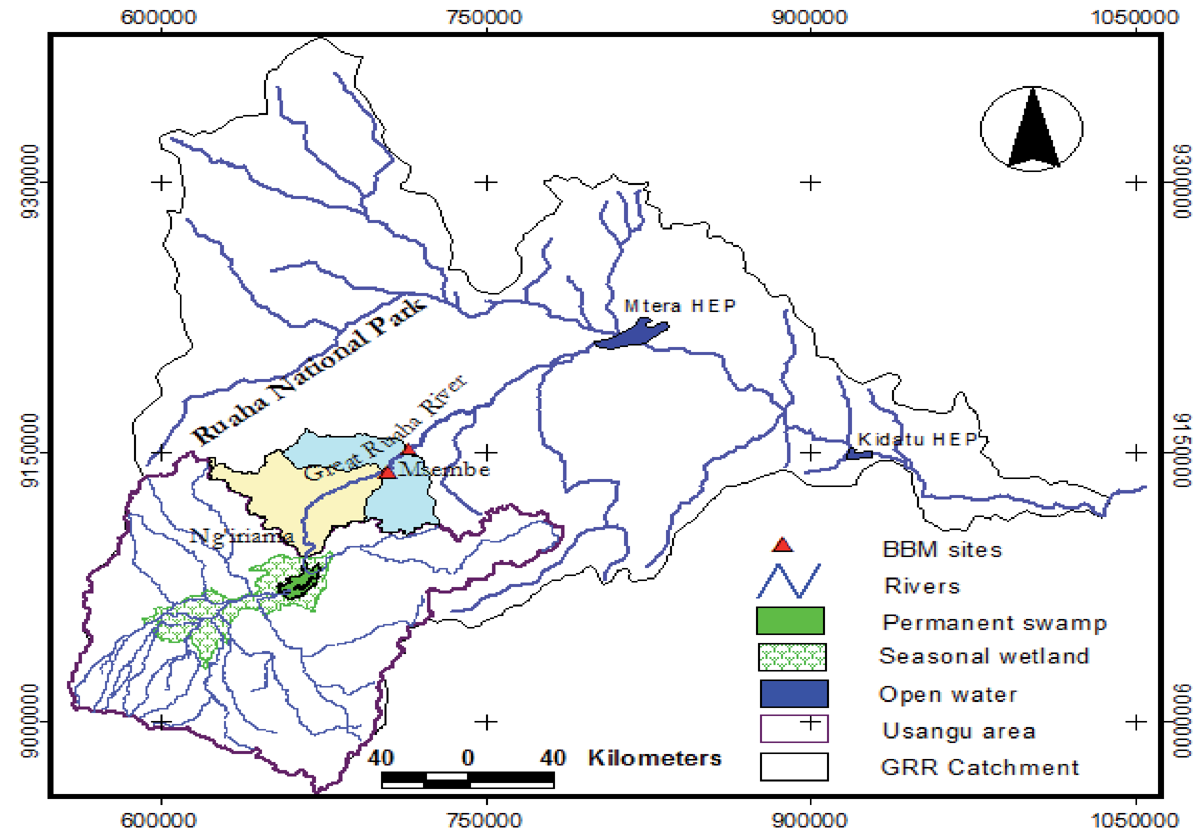
The wetland assessment acknowledged the problems facing the wetland and its connection to the downstream river, and set out to understand how this wetland functions and how it integrates with the river. In this it had the objective not only to consider the flow requirements but also the remediation options.

Initial studies on the system, being constrained by a lack of ecological data, made use of the desktop reserve model (DRM). The model was developed to provide initial estimates of ecological flow requirements for rivers in South Africa (Hughes and Munster, 2000). Despite its wide application, the model is limited making it very difficult to evaluate the results when there are no ecological data available to confirm or deny the suitability of the estimated EF. Nevertheless, in the absence of requisite information, the model provided a first estimate that could later be evaluated when the ecological data become available.

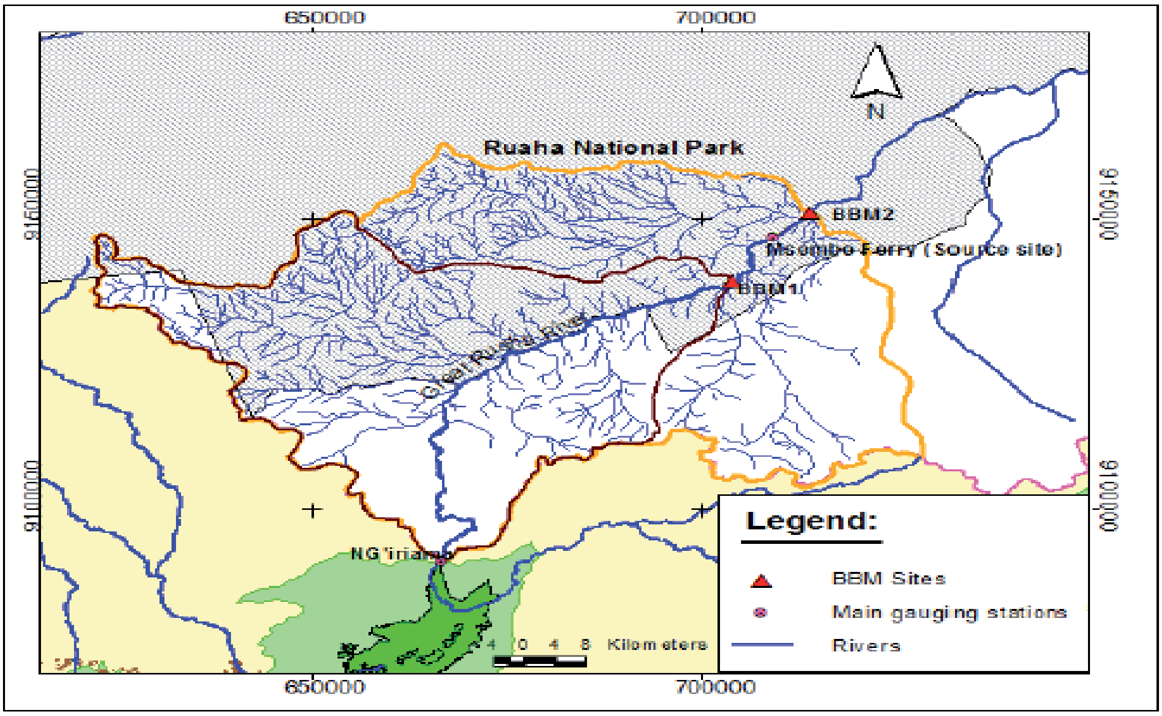
For the WWF project, the BBM was selected as the methodology for the EFA of the Great Tuaha River. It is among the most widely applied holistic method that addresses both the structure and function of all components of the river ecosystem (King *et al*. 2000).

Section B: Process to define areas of study and assessment

Social and management priorities have clearly identified the catchment from the upper reaches of the Great Ruaha, together with its tributaries, to the lower end of the Ruaha National Park, as the portion of the larger catchment most needing management intervention. This area thus forms the boundary of these studies.



Map illustrating the BBM sites used for the EF assessment for the Great Ruaha
(WWF Tanzania Country Office (WWF-TCO). 2010)



Map showing the Usangu wetland and the two BBM sites for the wetland (WWF Tanzania Country Office (WWF-TCO). 2010)

The multidisciplinary group of specialists chose two representative sites of the MGRR in the RNP upstream and downstream of Msembe. The selected sites exhibit fluvial processes characteristic of the macro-reach and also incorporate habitat diversity. Consideration of the sites to other issues such as ease of accessibility, suitability for measuring a rated hydraulic cross-section etc was also given.

Section C: Evaluation of the original & present state of the systems

While there has been extensive investigation of the Great Ruaha and the associated Usangu wetlands, the bulk of this investigation has been based on existing hydrological information. This information has been used to good effect to describe the hydrological situation in the catchment and in particular the role of water users who are contributing to a stress water situation in the basin. Good examples of these reports are Lankford et al (2004), Kadigi et al (2008) and Kashaigili (2005, 2006, 2007, 2009).

In the WWF study, (WWF Tanzania Country Office (WWF-TCO). 2010), the Present Ecological State (PES) of each site was considered and ranked from A (natural) to F (critical/extremely modified). The Trajectory of Change, and Ecological Importance and Sensitivity (EIS), and Ecological Management Category (EMC), (summarising the overall objective or desired state for each site, ranked from A (natural) to D (largely modified)), was also considered.

For the Usangu wetland, similar undertakings to the river were made, PES, trajectory of change etc. The wetland EFA also assessed the extent to which the proposed flow restoration options might have an impact on the GRR.

Hydrology

Importantly, there is some knowledge of the flows that were in the river before developments began (but only post 1958), usefully at Msembe within the Ruaha National Park and thus downstream of the Usangu wetland (data from the SMUWC 2002 reports). There is then some data representing the present hydrological situation, thus enabling a determination of the degree of departure of the present state from the natural.

It is probably necessary in this review to divide the work done in this basin into two broad zones:

1. The catchment upstream of the Usangu Wetland and the Usangu wetland itself

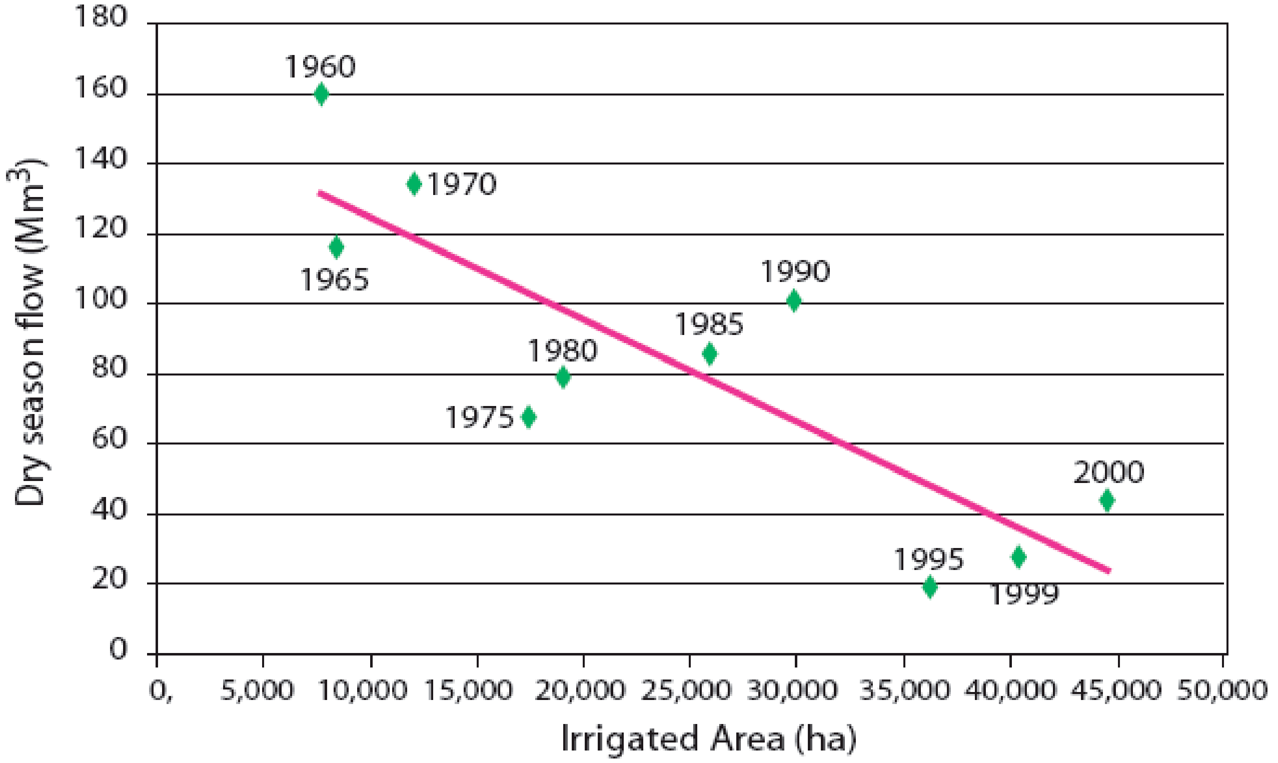
2. The river downstream of the Usangu wetland as it flows through the Ruaha National Park.

Upstream catchment

There is considerable work which describes the production but more specifically the use of water in the upstream catchment and as the water crosses the plains and enters the perennial Ihefu Swamp. A report by Mwakalila (2005) described the use of water in the Ruaha, identifying that a large portion of the water is abstracted during the dry season, much of this for irrigation. It is also suggested that this abstraction is more than necessary for crop production.

The report by authors Kashaigili et al (2006) further added to this by noting that the input of water to the Usangu Wetland declined by up to 70% over the dry months, over the time period from 1958 to 2004. Again, the main reason was abstraction for irrigation. This resulted in the decrease in the size of the wetland by some 40% during the dry season.

The report from the WWF (WWF Tanzania Country Office (WWF-TCO). 2010) documents in detail the recent understanding of the hydrology of the basin. Of particular interest is a section which summarises the causes of dry season degradation in the river, following documentation of the cessation of flows in several recent years. The figure below illustrates the impact of increasing irrigation on the degradation of low flows.



Downstream river

There has been some consideration of the flow situation in the downstream portion of the river where it flows through the Ruaha National Park where there is clear indication that things in the Park at not well, mainly due to the failure of natural flow regime (McCartney et al 2007). They also mention that large animal trampling of the river banks has led to widening of the river and silting of water holes in the riverbed.

Wetland hydrology

In the WWF project (WWF Tanzania Country Office (WWF-TCO). 2010) the objective was to carry out a hydrological analysis of the Ihefu wetlands that would characterise the wetlands hydrology, to assist in the EFA of the Usangu wetlands. A water balance mode was used for this. The figure below gives a clear indication of the change in flows being experienced by the wetland, indicating the “threshold” level.

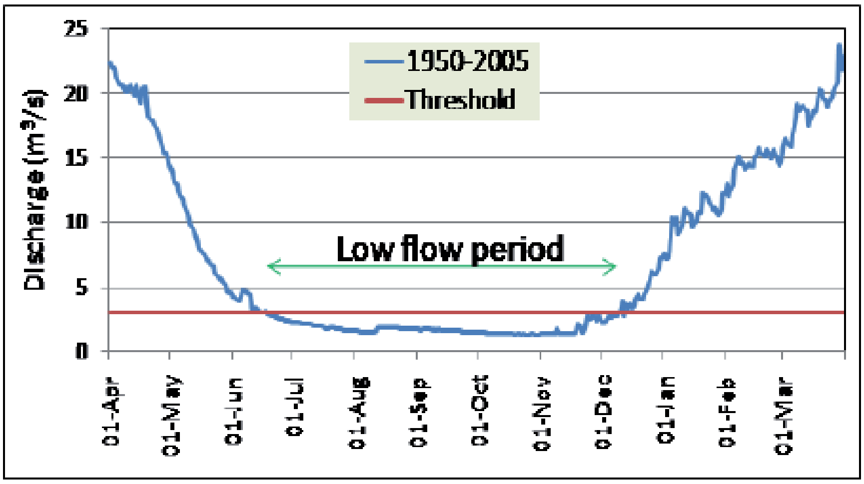


Figure 30: Low flow season identification of Ndembera at Madibira in the Ihefu wetlands catchment

Other ecological characteristics

There was no initiative during the earlier projects in this basin to define the aquatic ecosystem characteristics of the rivers in this system. The 2010 report (WWF Tanzania Country Office (WWF-TCO). 2010) does indeed document such characteristics as summarized below:

Hydraulics

Cross sectional surveys at the two river sites were carried out and used to calibrate a hydraulic model. A report describing the hydraulics study undertaken as part of this EFA is available from WWF TCO and RBWO.

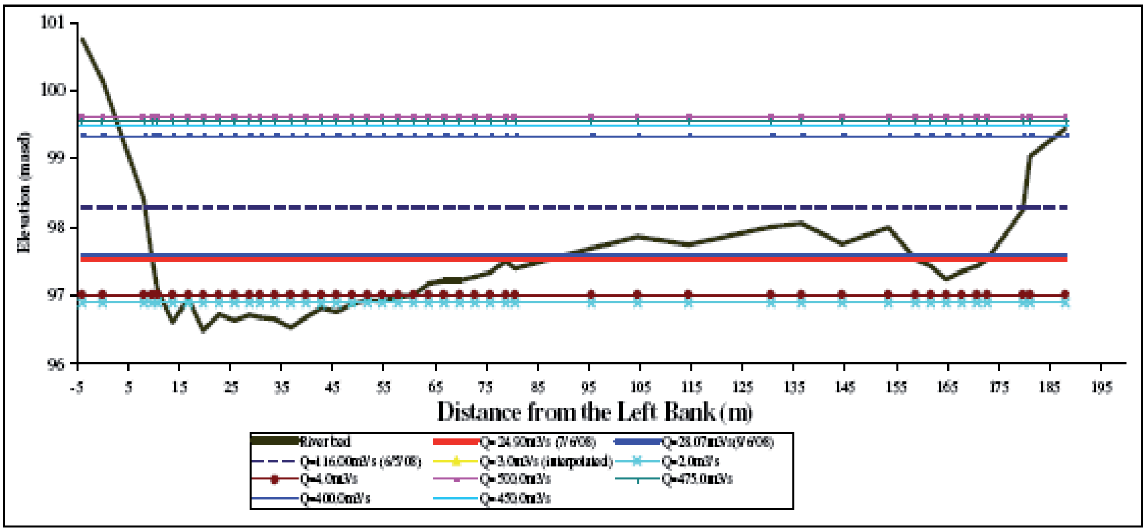


Figure 12: Water surface levels at BBM1 for various flow volumes

For the Usangu wetland, detailed hydraulic analysis was also carried out by developing rating relationships. Thus, the product was a series of relationships between stage and other flow parameters that were used by the team of specialists to arrive at water management scenarios in the Ihefu wetland system. These relationships included flow discharge, inundated surface area, and volume/storage.

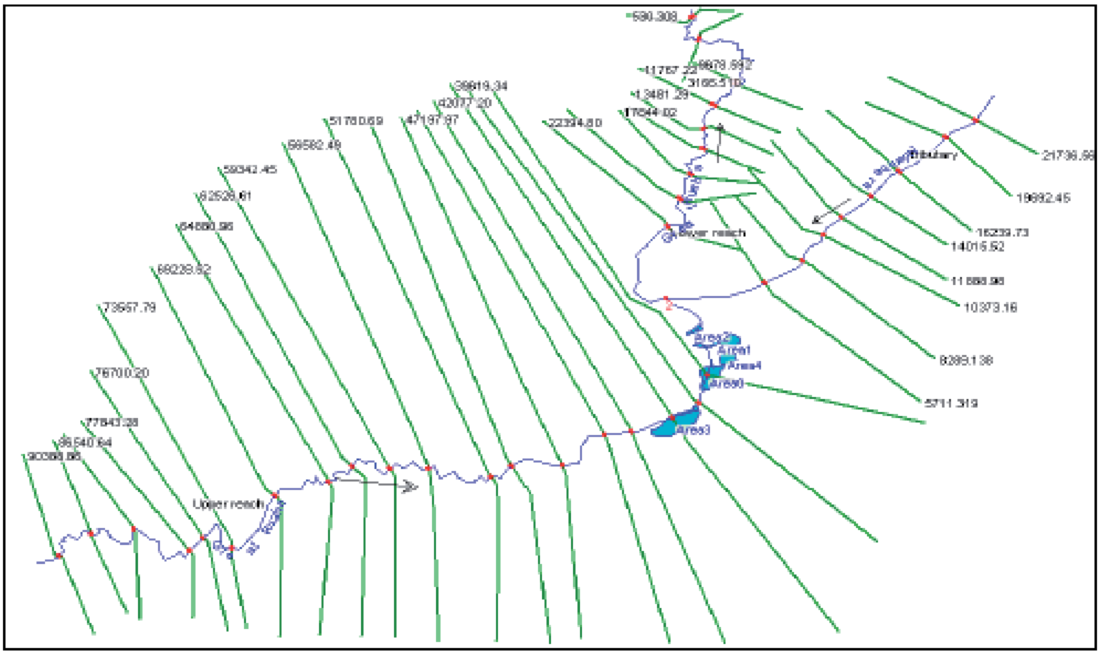


Figure 36: Strategically-placed cross sections for hydraulic model input

This hydraulic analysis of the wetland was undertaken in great detail, and will not be discussed in detail here as this is a specialist approach.

Geomorphology

To understand impacts that result due to changing flows of the GRR, the configuration of the GRR catchment was determined, the river channel geomorphology was assessed and the river channel characteristics were described. Based on Digital Elevation Models (DEM), generated from the Shuttle Radar Topography Mission (SRTM), 90 m resolution satellite, the Ruaha basin was delineated, the long profile of the main rivers calculated and geomorphologic units of the river channel established.

On the two BBM sites geomorphologic characteristics of the river were described, geomorphologic units that regulate flows were identified, and sediments characteristics assessed.

Riparian vegetation

As part of the BBM component riparian vegetation was sampled at the two BBM sites using the Quadrat technique (along the pre-determined transect lines at a cross section) which were surveyed for hydraulic analysis.

A report describing the riparian vegetation study undertaken as part of this EFA is available from WWF TCO and RBWO.

The objective of the Usangu wetland vegetation study was to assess the ecological importance of the wetland vegetation ecology in relation to its accrued functions. It included collecting information such as species diversity, abundance, and the presence of plant species that would assist in determining minimum water needs for aquatic and terrestrial biota. The assessment of water requirements in the Usangu wetland was expected to provide the critical baseline data regarding the maintenance of wetland vegetation communities, species distribution patterns, and the quality and quantity of water required to maintain the individual functions and processes in the ecosystem in the context of human development needs and biodiversity conservation needs.

Fish

Fish samples were collected by gillnets and a seine net and arranged according to environmental guilds ranging from moderately to highly sensitive to flow timing and/or quantity.

The fish fauna of Usangu Wetland is one of the well-studied biota in the Tanzanian river basins. Much of the description of fish species of Usangu Wetland is embodied in the works of SMUWC (2001).

The Shannon-Weaner diversity index was used to assess diversity and thus to imply ecosystem health. The fish diversity indices representing the wetland were wide ranging but the computation of analysis of variance (ANOVA) showed that there were no significant differences in fish species diversity and evenness between the three sampling sites. Although ANOVA did not show significant site differences in species diversity, it seems biologically significant that only two species of fish were caught in each of the Ruaha Ponds and Ng'iriama sites, despite the fact that the same types of fishing gear and effort were used across the three sites. There is concern that the use of ANOVA here has not yielded a satisfactory explanation and maybe should be omitted.

Aquatic invertebrates

In the WWF document the targets indicate that SASS version 4 was used, but this is not documented in the methods for the assessment. In fact SASS version 4 has since 2002 been superseded by SASS version 5 which is a considerable upgrade. It is unfortunate that this method was not adopted.

The Shannon-Weaner diversity index was also computed for macroinvertebrates at each of the sampling sites, in order to account for their species richness and evenness. The SASS index was used to determine the ecological health as indicated by invertebrates. Unfortunately the SASS index is well known to be limited in wetland situations, as a predominance of invertebrate families are inclined to be tolerant of low oxygen levels which often occur in wetlands and thus tend to indicate a poor state of health. Furthermore, setting the SASS score and ASPT into categories as given, i.e. that scores (indicating ASPT) of 0-2 signifies a highly impacted stream, 2-4 as impacted stream, 4-6 as slightly impacted stream, and >6 as good quality stream should really be site specifically determined making use of an understanding of the ecoregion and possibly reference sites. The average scores computed for the three sites define all of them as slightly impacted sites which may not a sound conclusion.

The report notes that the assessment of ecological health of the Usangu wetland is a problematic process, since it is anthropogenically stressed and is a dynamic ecosystem. Indicators of anthropogenic stress, such as declines in diversity and abundance, changes in biomass and primary production, and retrogressive succession may be difficult to apply in the wetland. They note that the present assessment is a cautionary lesson in the power of unchallenged paradigms in shaping scientific and popular opinion about the current change of vegetation communities in Usangu wetland.

Socio-economic situation

There is much information on the socio-economic situation revolving around the use of water. This is documented in the section below on "Importance and sensitivity of the systems".

Section D: Evaluating the importance and sensitivity of the systems

While several reports note that the importance of the system is well appreciated by society, there is no indication that an evaluation of the importance and sensitivity of the actual ecosystem has been carried out. While there is extensive information on the importance of the river in support of livelihoods, there has not been any systematic overview of the importance of the river ecosystem *per se* at a local or regional scale (other than how it impacts on the functioning of the ecosystem in the Park and on the mega-fauna forming part of the tourist trade). There has also not been any been any detailed evaluation of the sensitivity of the river ecosystem to changes in the nature of the river including its flow. Such investigations are imperative in order to properly relate the amount of water, and the quality of water, to the sustained use of the ecosystem services provided by the river.

There is considerable documentation of the importance of the upstream river flow to sustain the ecology of the Usangu wetlands and the Ruaha National Park, but this mainly from a use point of view e.g. sustaining tourism in the National Park.

In recognition of its biological importance, the Usangu area was designated an Important Bird Area by Birdlife International (Mtahiko et al. 2006). In 2000, the Ihefu Swamp and its surroundings were incorporated into the Usangu Game Reserve and more recently the Reserve has been incorporated into the Ruaha National Park. However, the designation of the Ihefu as a Ramsar Wetland of International Importance has been postponed because of its currently degraded state (Mtahiko et al. 2006). The motivations for this should contain information on the ecological importance of these systems but this is not apparent in the documents that have been reviewed.

From a conservation standpoint, the Usangu wetlands are amongst the most valuable ecosystems in Tanzania, providing habitat for over 400 bird species and numerous other flora and fauna (Kamukala and Crafter, 1993). Furthermore, the wetlands support numerous livelihood activities, many of which depend on water from the river, including agriculture, cattle grazing and traditional fisheries, as well as small-scale industries such as brick-making (Kashaigili and Mahoo, 2005).

The report by authors Kashaigili et al (2006) notes the importance of the Great Ruaha River and the Usangu wetland, noting the importance of the irrigation and hydroelectric uses of the river. They also note that in earlier times, the resources were used for a <u>greater variety</u> of socio-economic uses ranging from fishing to ritual prayers. The more recent drying up of the river during the dry seasons, has created social problems as people have lost access to the resource. It is also having adverse ecological impacts especially on the Ruaha National Park where stream flows and the cessation of flow in particular, are having negative impacts on many aspects of the terrestrial ecosystem of the Ruaha.

According to the 2010 report (WWF Tanzania Country Office (WWF-TCO). 2010) , flows in the river are the major driver of conditions in the park, for the following reasons:

- The riparian and floodplain vegetation, which depends on the flows and water levels in the river, are the critical habitat for the large mammal populations during the dry season. A range of low-flows and floods is necessary to maintain root moisture, growth, seed dispersion/germination, and seedling establishment.

- The riparian vegetation plays a critical role in stabilising the river banks, particularly during floods. If the riparian vegetation disappears, bank and riverbed erosion will result in the destruction of characteristic channel forms and habitats, typically with excessive sedimentation of the channel – a condition which cannot be rehabilitated in less than decades or centuries.

- The loss of low flows during the dry season results in a series of disconnected, isolated pools (at approx. one per kilometre, but concentrated in the upper middle section of the river). Hippos, crocodiles and fish are crowded into these refuge areas, resulting in anoxic polluted conditions, and aggressive interactions. Terrestrial mammals are also concentrated around the remaining water, resulting in local overgrazing, especially of riparian vegetation. This exacerbates the effects of vegetation loss and erosion described above.

- The concentration of game – both terrestrial and aquatic, increases aggression and the incidence of parasites and disease (e.g. anthrax outbreak in 2003).

There are strong statements about the conservation importance of the Usangu Wetland in the WWF (2010) report. The densely vegetated Usangu wetland may be regarded as the "kidney" of the Usangu landscape, because of the functions it performs in hydrological and chemical cycles as a downstream receiver of wastes from runoff from both catchment and agricultural sources. The value of the wetland has now been recognised and translated into protection through the creation of national parks. Having come more recently to the attention of the global scientific community, it needs to remain the focus of interest to conservation minded people and organisations, as its degradation trend has been tremendous and is easily recognised through loss of species diversity and habitat.

Signs of the geological history of the river indicate that it changed from a west flowing to east flowing river during the formation of the Rift Valley, and during this event the streams draining the Usangu Wetland took some of the species with them, some of which have remained unchanged, while others have evolved into new species through isolation. Since fish fauna of the Usangu Wetland bear the fingerprint of this geological and evolutionary shift, its conservation is of paramount importance. Genetic stocks of tilapia were also found to be uniquely important in support of aquaculture ventures (internationally) as hybrids uniquely form male offsprings only.

Section E: Quantifying the relationship between river flow and the ecosystem

The chosen approach for early projects on this river relating the environmental water requirement to the hydrological situation was to use the South African Desktop Reserve Model (Hughes and Hannart 2003).. Application of this model in countries other than South Africa is relatively limited, however it has been used successfully in Swaziland, Zimbabwe and Mozambique. In the absence of any specialist knowledge of the relationships between hydrology and the ecological functioning of the Great Ruaha river, it was felt to be the most appropriate tool to use in the earlier studies. However, given that it is underpinned by empirical equations developed specifically for South Africa, and based in ecosystems in South Africa, and is also only designed as a "low-confidence" approach, the results must be treated with caution. Nevertheless, the results are of value as they indicate the probable situation in the river. Further details of the application of the model to the Great Ruaha River are given in Kashaigili *et al.* (2007).

Any investigation such as this needs to be based on the "original" or "natural" flow situation, this in order to determine the extent of change in the present time. Thus, to estimate the environmental flows the model requires a naturalized flow series as input. A completely naturalized flow series was unavailable, so monthly flows for years 1958–1973 (i.e., the least modified period) were used as input.

The Desktop model results are presented in the table below. These indicate that, to maintain the river at class C/D, requires an average annual environmental flow allocation of 635.3 Mm^3 (equivalent to 21.6% of MAR) at Msembe Ferry and an absolute minimum flow of not less than 0.6 m^3s^{-1}. This is the average annual "maintenance flow"; the sum of the maintenance low or base flows (i.e., 15.9 % MAR; 465.4 Mm^3) and the maintenance high flows (i.e., 5.8% of MAR; 169.9 Mm^3). The drought-low-flows correspond to 10 percent MAR (i.e., 293.3 Mm^3).

Another report by McCartney et al (2008) provided information on the environmental flows related to the Usangu wetland. They note that to maintain minimum downstream environmental flows requires a minimum <u>inflow</u> of $7m^3s^{-1}$, which is approximately 65% greater than occurs currently, and necessary to maintain the downstream dry season environmental flow of $0.5m^3s^{-}$

The minimum ecological flow requirement of 0.5 m^3s^{-1} was confirmed by the ecologist of the Ruaha National park, based on expert judgment (Kashaigili *et al.*, 2007).

There has been considerable work done on the relationship between the river flow and the flooding of the wetland, but again only a limited amount of work has been done on the ecological functioning of the wetland. The report by authors Kashaigili et al (2006) documents the relationship between the water requirements of the Usangu wetland and the flow of the river both upstream and downstream.

TABLE 16.
Summary output from the desktop reserve model applied to the Great Ruaha at the Msembe Ferry, based on 1958-1973 monthly flow series.

Annual flows (Mm³ or index values)

MAR	=	2,936.30	Total environmental flow	=	635.30	(21.6% MAR)
S.D.	=	2,932.16	Maintenance low flow	=	465.44	(15.9% MAR)
CV	=	0.996	Drought low flow	=	293.26	(10.0% MAR)
BFI	=	0.89	Maintenance high flow	=	169.86	(5.8% MAR)
CV (SON + FMA) Index	=	1.541				

Month	Observed flow (Mm³)			Environmental flow requirement (Mm³)			
				Low-flows		High-flows	Total-flows
	Mean	SD	CV	Maintenance	Drought	Maintenance	Maintenance
Jan	279.452	536.153	1.919	35.57	13.33	37.15	72.72
Feb	451.068	505.184	1.12	67.55	22.43	18.58	86.12
Mar	682.947	705.617	1.033	106.02	72.57	86.05	192.1
Apr	803.089	777.042	0.968	131.22	93.15	18.58	149.80
May	405.689	318.063	0.784	71.75	50.69	2.30	74.05
Jun	123.363	72.367	0.587	22.05	15.69	0	22.05
Jul	56.774	25.68	0.452	10.12	7.22	0	10.12
Aug	35.002	19.179	0.548	6.22	4.45	0	6.22
Sep	21.618	10.842	0.502	3.82	2.75	0	3.82
Oct	14.729	7.644	0.519	2.58	1.87	0	2.58
Nov	10.808	5.974	0.553	1.87	1.37	0	1.87
Dec	51.762	109.609	2.118	6.67	4.77	7.21	13.88

Source: Own analysis using desktop reserve model

The above summarises the output of the Desktop model that was applied following extensive adjustment to the model as a result of ecological differences between South Africa and Tanzania. One of the limitations of this output from an ecological point of view, is that the output is expressed in a monthly time step, which is somewhat at odds with the instantaneous time step (daily at least) which is necessary for a full ecological interpretation. This is particularly relevant during flood events where the eventual peak of a flood has to be crudely estimated as it may form only a small part of a monthly flow. During the low flow period, which could be considered to be the most important in this case, this is less of an issue as the flows are less variable over the month.

The 2010 (WWF Tanzania Country Office (WWF-TCO). 2010) report contains more information on the flow requirements of the ecosystem – for the Usangu wetlands study fish were considered according to flow requirement guilds. There is good ecological information that exhibits understanding of the flow requirements of the fish. The flow requirements for fish were considered in the full variety of flow conditions.

The 2010 report (WWF Tanzania Country Office (WWF-TCO). 2010) considers the vegetation of the Usangu wetland – stating that "the vegetation communities in the Usangu wetland need a minimum water level of 0.81m. This level is required to support the ecological functions in the wetland, regardless of the seasonal changes that might occur throughout the year, or the climatic changes over a number of years.". Depth requirements for each vegetation species are also given. Unfortunately no evidence for this information is given. An extracted example of the type of information provided by the 2010 project is provided below (note this is for the wetland).

Dry season low flows for maintenance years (November) at WBBM 1

Table 78: Recommended flows for the dry season low flows for maintenance years (November) at WBBM1

Indicator	Average Velocity (m/s)	Average Depth (m)	Discharge (m^3/s)	Motivation	Consequences of not providing this flow
Fish	0.20	1.11	40.0	The low flows during the driest month of a mainrenance year are required to • inundate more wetland habitats to increase habitat diversity • inundate a greater area of the wetland channels to permit fish passage over obstacles • inundate pools to improve water quality (more favourable habitats for fish). Increased inundation of the main channel will provide a variety of habitats for resident fish species. This would provide more resources (space, food, etc) than that available during the dry season. This allows fish to grow faster.	Limit available habitats for *Labeo* and juveniles of *Barbus* sp occurring in that part of the river. It may result in lowering fish standing biomass in that reach of the river.
Invert.	0.15			The low flows during the driest month of a mainrenance year are required to • inundate more wetland habitats to increase habitat diversity. • Enhance downstream drift of animals and flush out areas of poor quality water accumulated during the dry season.	Could curtail downstream drift of invertebrates and enhance mortalities due to poor water quality. It may result in lowering macroinvertebrate standing biomass in that reach of the river.

Biotic requirements

As noted earlier, the earlier reports reported on by Kashaigili and partners did not examine the actual requirements of the ecological elements located at these sites. Instead, by using the Desktop Model, those relationships that have previously been determined for the South African situation, have been used for the Tanzanian situation. Due the fairly wide differences between the ecosystems of these countries, it can be expected that there will be large inaccuracies in the determination of the flow requirements of the Great Ruaha.

The final flow requirements determined by the BBM method and reported on in the WWF report (WWF Tanzania Country Office (WWF-TCO). 2010) are summarized as flow duration curves. An example of such a curve is presented below.

The table below, taken from the WWF (WWF Tanzania Country Office (WWF-TCO). 2010) report, gives an indication of the type guidance given to understand and implement the environmental flows, provided for each indicator. Only that for fish is documented below.

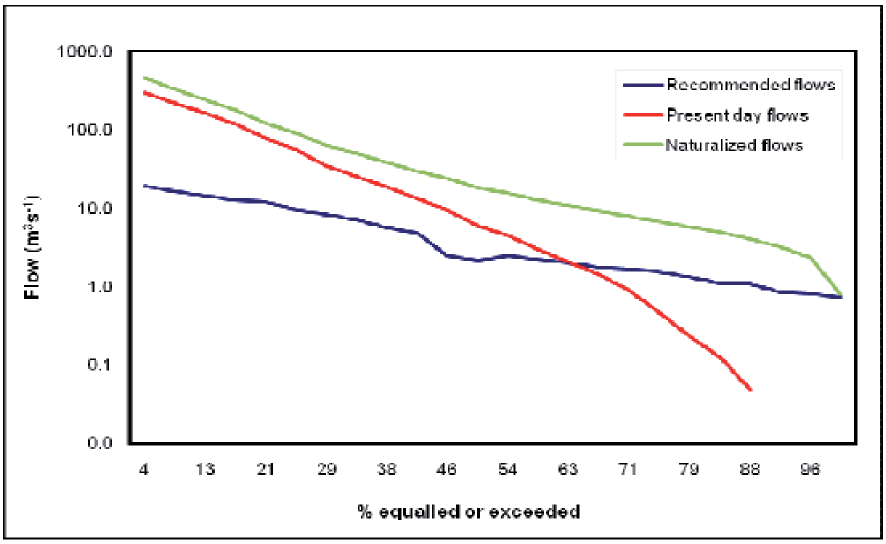


Figure 11: Flow duration curve for recommended maintenance and drought flow for BBM1

Table 20: Dry season low flows for maintenance years (November) at BBM1

Indicator	Max Velocity (m/s)	Max Depth (m)	Discharge (m^3/s)	Motivation	Consequences of not providing this flow
Fish*	0.44	0.454	2.5	The low flows during the driest month of a maintenance year are required to • inundate more riffle sections to increase habitat diversity and therefore fish species diversity • maintain active channel flows to inundate benches and sustain emergent vegetation that fish need for shelter/cover • permit more fish passage over obstacles • flush out pools to improve water quality (more favourable habitats for fish). The primary motivation for maintaining low flow flows in a dry season of the maintenance year would be to inundate the main channel (especially vast area of riffles and benches) to provide a variety of habitats for resident fish species. The recommended discharge results in an average hydraulic depth which is enough to cover appreciable portion of mid-channel riffles. The resultant maximum velocity is also suitable for *Chiloglanis* and juveniles of other species which need appreciable inundated vegetation for cover/shelter and feeding.	Will curtail optimal growth rate of many species and present diversity. It may result in lowering fish standing biomass in that reach of the river.

Note there is good information on the confidence of the assessments and interpretations given for each component of the wetland.

Section F: Setting a vision for the river basin and development of scenarios

Vision for the basin

The Government of Tanzania is committed to ensuring that ''year-round flow'' is re-established by 2010, however, exactly how this is to be achieved is not clear. In the recent studies, to reflect the importance of water abstractions for local communities, the desired ecological condition of the Great Ruaha River was set as C/D (i.e., moderately to largely modified). Unfortunately the ecological consequences of setting the ecological condition in this category, have not been documented.

Since the early 1990s the Friends of Ruaha Society has been strongly advocating for measures to be introduced to maintain dry season minimum flows through the Park (Fox 2004).

According to the 2010 report (WWF Tanzania Country Office (WWF-TCO). 2010) the overall objective (vision) of the MGRR EFA is: *"Acknowledging the flow changes which have and are occurring in the middle Ruaha: To recommend a modified flow regime which will maintain the biodiversity, processes and functions of the RNP, and will reverse the trajectory of degradation which the present flow regime is responsible for".*

Scenarios for the basin

As problems have emerged with the flows in the Ruaha basin, and the negative impacts have been felt in society, so have a number of plans and options for the management of the over-utilised resource been developed. Yet, there is no single scenario analysis which captures the full range of options. Some of the key investigations that have been done are summarized below.

There has been a flurry of investigation into the causes of the drop in dry season flows in the Great Ruaha river – with the IWMI report – McCartney et al. (2007) being a good example. Another key set of reports was the programme Sustainable Management of the Usangu Wetland and its Catchment (SMUWC, 2001).These reports have set out to propose ways to rectify the situation but as these are mainly involved in the solution to the problem, and not on the environmental flows *per se*, they are not discussed in detail here.

Tradeoffs between the environment and other anthropogenic requirements have also been considered e.g. Kashaigili et al (2006), who estimated that, to maintain absolute minimum desired flows downstream of the Eastern wetland, current abstractions would need to be reduced by approximately 60%. The reduction in abstraction to meet environmental water requirements is likely to affect water dependent livelihoods. Consequently consideration is given to alternative options, including trade-offs between different environmental needs. Several solutions to this problem are proposed, but are not discussed here in detail as they are not relevant to this review. Some first scenarios are briefly summarized below.

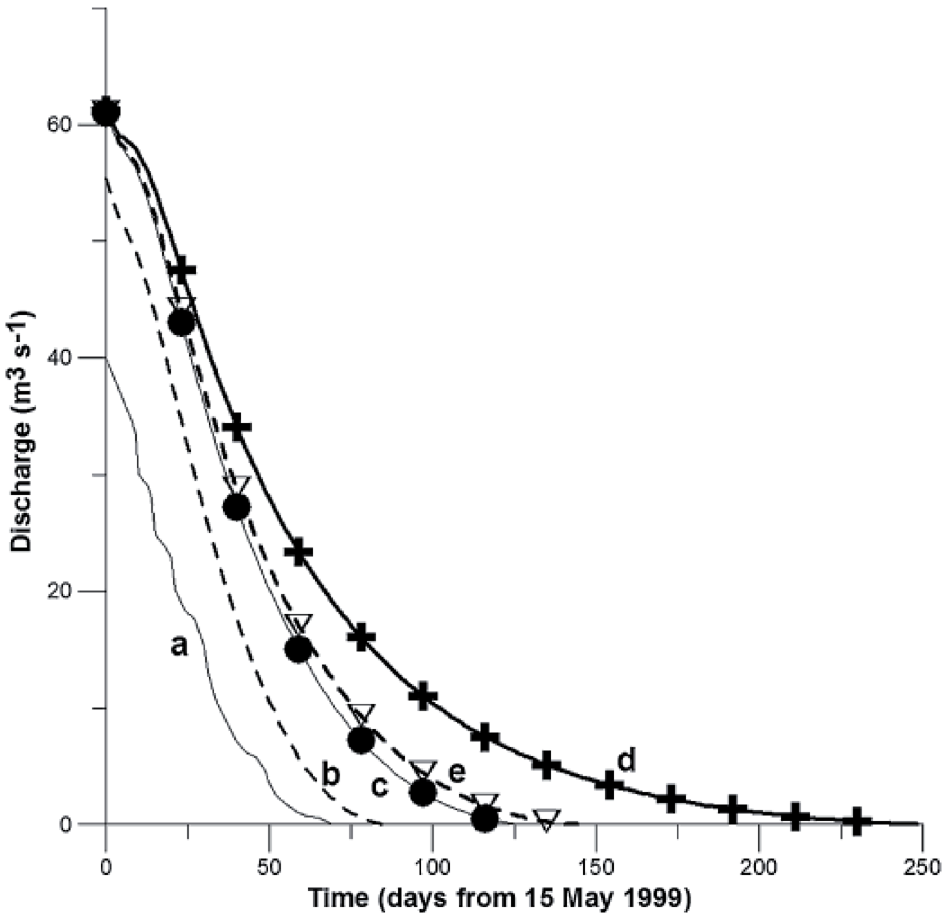


Figure 8. Time series plot of the predicted flow in the GRR at Msembe during the 1999 recession period for various scenarios. (a) present conditions; (b) present conditions minus wet season irrigation; (c) present conditions minus both wet season and dry season irrigation; (d) no irrigation and no livestock in the eastern Usangu wetlands; and (e) present conditions but the dry season irrigators return 25% of the water to the river and no livestock in the eastern Usangu wetlands.

The above figure (Matahiko et al 2006) shows the possible flows resulting from a range of different scenarios, including the present condition and includes different options of irrigation and livestock keeping. Understanding these would all assist with decision making.

The authors Kashaigili et al (2006) noted the need to balance environmental water requirements and livelihoods issues under the prevailing water resource conditions, four possible flow scenarios were formulated. In each case the wetland model was used to compute the inflows to the Eastern Wetland that is required to maintain the specified minimum downstream flows for the period 1999 to 2004.

1. Ensuring a Dry Season Outflow of 2.84 m^3s^{-1} (i.e., corresponding to the "natural" Q_{95})

The inflow required to achieve this would be significantly greater than the perennial river flows measured upstream of the off-takes on the Usangu Plains between 1998 and 2003 and hence could be considered as an unrealistic option.

2. Ensuring the Estimated 2-year Return Period Environmental Flows

The average dry season inflow needed to maintain downstream environmental flow requirements with a return period of 2 years was estimated as slightly more than the average dry season flow in the perennial rivers upstream of the abstractions on the Usangu Plains and thus was also considered as an unrealistic option.

3. Ensuring the Estimated One-year Return Period Environmental Flows

The average dry season inflow required to maintain downstream environmental flow requirements with a return period of one-year was estimated to be close to the current average dry season inflow in the perennial rivers upstream of the Usangu Plains. However, allocating this amount of water for environmental needs would leave very little for irrigation and other livelihood support activities.

4. Ensuring an Absolute Minimum Flow of Between 0.5 and 0.6 m^3s^{-1}

The absolute minimum dry season flow required to maintain conditions (i.e., temperature and dilution requirements) suitable for wildlife in the pools and the river in the Ruaha National Park during the dry season was judged to be 0.5 m^3s^{-1} (Ecologist for the Ruaha National Park, personal communication). This is similar to the absolute minimum flow of 0.6 m^3s^{-1} derived from the desktop reserve model for October. This would require an absolute minimum dry season inflow of about 7.0 m^3s^{-1} which is approximately 3.25 m^3s^{-1} greater than current average dry season inflows. To maintain this average inflow would require the available dry season surface water resource to be divided in the ratio of 80 percent for the environment (i.e., 7.0 m^3s^{-1}) and 20 percent for anthropogenic water needs (i.e., 1.50 m^3s^{-1}). In absolute terms this would require current dry season abstractions to be reduced from approximately 4.25 m^3s^{-1} to about 1.50 m^3s^{-1} (i.e., a 65% reduction).

Maintenance of aquatic ecosystems is a pre-requisite for sustainable development. In an environment of increasing water scarcity, the allocation of water must consider the environmental implications, however, estimating water requirements for wetlands in water-stressed catchments, in which peoples' livelihoods are highly dependent on water abstraction, is a far from trivial task. It is essential that consideration is given not only to environmental requirements, but also to the economic and social implications of maintaining environmental flows. This is the importance of generating scenarios, so that possible futures can be described so that management of the system moves towards a known and accepted outcome.

Section G: Implementation of environmental flows

While the above scenarios describe possible futures, achievement of these would only be possible with careful examination of management options that would determine how the system is to be used and water allocated. Some very creative "out of the box" thinking has been done in proposing possible solutions to the apparent impasse that exists between the allocation of water for economic gains and for the environment.

A WWF sponsored report (Anonymous 2008b) and a subsequent workshop to make decisions, discusses a range of solutions that include institutional changes and various technical, environmental, agricultural and economic options.

Options were broadly classed into a number of categories:

- *Technical (engineering) options*: the construction of infrastructure, storage, and development of transfer schemes or the abstraction of groundwater;

- *Institutional options*: development of particular institutional arrangements and water resource management instruments;

- *Environmental options*: management of land or land-use to retain environmental services and functions;

- *Agricultural options*: management of agricultural activity and adaptation of agricultural practices; and

- *Economic options*: linked to economic development and the provision of alternatives to current economic practices.

The above are all described in some detail and the various options evaluated as well as the feasibility of implementation considered. Consideration is also given to the practicalities of implementation for these options. In November 2008 a workshop was held to evaluate these options.

The workshop noted on a number of occasions that the task of identifying and selecting options to restore flows was particularly complicated by the lack of a detailed understanding of the environmental flow requirements in the GRR (in the RNP). The workshop expressed their frustration that the environmental flows study had not been completed and that the options discussion was preceding the environmental flows determination. However, the workshop accepted the 0.5 – 1.0 m^3s^{-1} hydrological flow requirement as the basis for assessment of options. It is noteworthy that this limitation has recently been overcome through the finalisation of the WWF report in 2010 (WWF Tanzania Country Office (WWF-TCO). 2010).

The workshop (Anonymous. 2008a, 2008b) concluded with the options that qualified for further investigation:

- impoundment of the Ndembera River (this option was later discarded partly as it was going ahead anyway and is a long term option)

- transfer from the Ndembera River to N'Giriama – this was the favoured option but detailed consideration could not be given to it without the complete environmental flow assessment for the Great Ruaha river being completed. It was hoped that this would be available by January 2009.

- transfer over the sill at N'Giriama

- raising the sill at N'Giriama (impoundment of *Ihefu*l) (this option was later discarded)

- improved water resources management (institutional option), including water conservation and demand management in the agricultural sector – this was seen as the best long-term solution

Another report (Kashaigili et al 2005) identifies options that include: (a) conducting purposive training and awareness creation to communities, politicians, government officials and decision makers on environmental flows, (b) capacity building in environmental flows and setting-up multidisciplinary environmental flows team with stakeholders involvement, (c) facilitating the development of effective local institutions supported by legislation, (d) water harvesting and storage and proportional flow structures design to allow water for the environment, and (e) harmonizing policies and reform in water utilization and water rights to accommodate and ensure water for the environment.

There is a great deal of advice on the implementation of catchment management practices that would assist in the recovery of environmental flows in the Great Ruaha River. The report by McCartney et al (2007) is an excellent example. Even climate change adaptations are considered (Kashaigili et al 2009) - the study found key adaptation benefits, including reduced vulnerability to drought and strengthened local water user associations and other regional institutions. As a result of the project interventions from 2003 to 2009, rural livelihoods became more profitable and water-sustainable, and local livelihood strategies were diversified. Regional ecosystems improved as a result of restoring river flows in some rivers, conservation of riparian vegetation and halting tree felling for charcoal production. As a result of these changes the communities and ecosystems in the Great Ruaha River catchment should be more resilient to emerging climate change impacts, yet the need for further physical interventions and institutional reform is identified. This positive outcome of environmental flow mitigation should be highlighted.

Existing implementation

The Ruaha River programme is well advanced in that details for implementation are being considered and indeed some has already been implemented. The partial canal closure program is already having some impact. Measurements indicate that dry season abstractions from the Mbarali River, a tributary of the Great Ruaha River, decreased from 1.454 m^3s^{-1} in 2003 to 0.577 m^3s^{-1} in 2004. The same trend was observed in the Kimani River where average dry season abstractions declined from 0.914 m^3s^{-1} in 2003 to 0.580 m^3s^{-1} in 2004 (RIPARWIN 2006). Since it was instigated in 2001, the inflows to, and hence the minimum dry season area of, Ihefu have increased slightly. The result is that downstream flows have also improved to some extent and the number of zero flow days have been fewer than would have been anticipated, based on the rainfall in recent years.

According to WWF, in 2006 a large section of the river flowed throughout the year for the first time in five years. Measurements taken below the main rice irrigation area in the upper catchment indicated that a minimum of one 1.0 m^3s^{-1} was maintained in the river at the peak of dry season, despite a drought. Preliminary analysis suggests that further improvements in river flows were achieved in 2007. This success is a result of collaborative efforts between WWF and partners at local, district and national levels to improve management of water and natural resources in the Great Ruaha River catchment. They focussed on a variety of measures, including:

- Involving and empowering communities and districts in equitable water resource management through the establishment of water user associations, as well as a committee that represents the entire catchment.
- Reducing water withdrawals for irrigation, especially in the dry season.
- Controlling the construction of illegal water abstraction infrastructures in the catchment.
- Training farmers in more efficient water use in rice production.
- Supporting the development of alternative livelihoods, away from agriculture, while reducing impacts on water and natural resources (e.g. beekeeping, batik dying, soap making).
- Developing alternative water sources.

These successes are most significant and a tribute to a resolute desire to improve a poor situation. All participants should be commended!

The WWF (WWF Tanzania Country Office (WWF-TCO). 2010) report provides thinking on ways to maintain environmental flows within the RNP during the low flow periods, without undermining the importance of the other problems experienced within the Usangu catchment and beyond. Solutions that may solve more than one problem are ideal – nevertheless, the primary focus of this work was on the drying of the GRR in the RNP. The summary represents an excellent initiative to implement EF in the river, providing information that will facilitate decision making. A summary of this is provided below.

Table 37: Summary of qualifying criteria assessment

Option	Qualifying criteria		Qualifies
	Flow restoration	Sustainability	
1. Ndembera impoundment	*qualify*	*qualify*	**YES**
2. Increased *Ihefu* storage	*qualify*	*qualify*	**YES**
3. Off-channel storage in the fans	*disqualify*	*qualify*	NO
4. RNP tributary impoundment	*qualify*	*disqualify*	NO
5. Groundwater storage	*disqualify*	*disqualify*	NO
6. Transfer: Nyaluhanga to Ng'iriama	*disqualify*	*disqualify*	NO
7. Transfer over the sill (Ng'iriama)	*qualify*	*qualify*	**YES**
8. Ndembera River transfer	*qualify*	*qualify*	**YES**
9. *Ihefu* canalisation	*disqualify*	*qualify*	NO
10. Groundwater abstraction	*disqualify*	*disqualify*	NO
11. Institutional options: improved WRM	*qualify*	*qualify*	**YES**
12. Environmental management	*disqualify*	*qualify*	NO
13. Increased efficiency of irrigation	*qualify*	*qualify*	**YES**
14. Other agricultural adaptation	*disqualify*	*disqualify*	NO
15. Economic options	*disqualify*	*disqualify*	NO

The table below (WWF Tanzania Country Office (WWF-TCO). 2010) summarises the final decision making process based on an assessment of the viability of each proposal.

Table 38: Summary of viability criteria assessment

	Option	1.	2.	3.	4.	5.	6.
		Ndembera impoundment	Increased wetland storage	Transfer over the sill (Ng'iriama)	Ndembera River transfer	Institutional options: improved WRM	Increased efficiency of irrigation
Feasibility criteria	Technical feasibility	1	-1	-1	1	1	1
	Financial feasibility	1	-1	-1	1	1	1
	Economic impact	1	0	0	0	1	1
	Environmental impact	-1	0	-1	0	1	0
	Institutional complexity	0	1	1	1	-1	-1
	Operational complexity	-1	0	0	0	-1	0
	Stakeholder acceptability	1	0	0	0	0	0
	Rollout considerations	0	0	0	1	-1	0
Results	"Feasibility"	2	-2	-3	2	4	3
	"Implementability"	0	1	1	2	-3	-1
	Overall Viability	**2**	**-1**	**-2**	**4**	**1**	**2**

Based on rigorous assessment and engagement with a broad range of stakeholders, three options emerge as viable:

1. Institutional strengthening and support to ensure improved water resources management;

2. Construction of an impoundment on the Ndembera River (Lugoda Dam); and

3. Transfer from the Ndembera River.

According to the WWF report (WWF Tanzania Country Office (WWF-TCO). 2010) of these three options, Options 1 and 2 is the focus of significant work being undertaken by the MoWI (Water Sector Development Programme and others). However, Option 3 (Ndembera Transfer) is currently not being explored in any detail by the mandated institutions. As this option is principally focussed on returning flows to the GRR (with some potential for small-scale agricultural production en route), it is entirely suited to this project (and the mandate of WWF) and possible follow-up phases.

At the conclusion of the GRR River EFA (WWF Tanzania Country Office (WWF-TCO). 2010), when these options were presented to stakeholders, it was recommended that a wetland EFA be undertaken specifically to investigate the likely impact, and the feasibility in terms of wetland flows, of these options on the Usangu wetland. The Usangu Wetland EFA programme was launched with an initial reconnaissance visit to Usangu which took place on 16th December 2009. This visit was aimed at gaining a synoptic view of the extent of the wetland habitats and selecting suitable/representative sampling sites, and finalising logistical arrangements prior to conducting the field work. The field sampling and assessments were then carried out between 20th and 27th March 2010.

The objective of the wetland assessment was to determine the response of the wetland to changing flow regimes, not only those caused by upstream abstraction, but also with respect to proposed engineering modifications:

- The construction of the Lugoda Dam

- The Ndembera transfer option.

Among other things, this study looked into how these alterations might affect wetland size and geology, and the consequences of this on biodiversity and ecosystem services.

From the above summaries, it is clear that implementation of EF in the Ruaha River is well advanced, with wide ranging consideration of how these environmental flows can be included into overall water resources management. This is an excellent start.

Resource Quality Objectives

The WWF study (WWF Tanzania Country Office (WWF-TCO). 2010) has developed flows and objectives for the different components of the ecosystem that need to be maintained. Examples are presented below:

Table 9: Geomorphological objectives and motivations derived at BBM1

Objectives	Reasons/motivation
To maintain low flows for channel maintenance	To provide continuous flows in the pools to prevent them being obliterated by sandy deposition
Maintain wet season high flows.	To allow entrainment of gravels and movement of point bars thus reducing lateral erosion of the left bank and allowing channel to re-adjust to the previous condition

Objectives such as this provide a useful perspective for each indicator that could be monitored as part of the EF for the river and indeed they are used to document Target Indicators for each component for each site, e.g.

Target indicators for geomorphology

Low flow quantitative level indicators: Water at the maximum depth of 0.5 m moves into the vegetation in the left bank, flows are capable of remobilising the sand materials in pools.

High flow quantitative level indicators: Water at a depth of 3 m flows overbank, and is capable of inundating and remobilising sand bars.

NOTE that the same approach was used for the EF assessment for the wetland.

Target indicators for invertebrates

The following target taxa will be used as indicators with the objective of maintaining abundances comparable to reference conditions: *Perlidae, Oligoneuridae,* and *Leprophlebiidae*: (riffles)

These are excellent examples of the development of RQOs – that they include both narrative and quantitative descriptions of the resource in a way that is suited to monitoring.

Summary of implementation initiatives described at a workshop to discuss EF in Tanzania (IUCN, 2010)

The Basin Water Officer provided information on a newly released flow assessment of the Great Ruaha to be shared and incorporated into the review. He noted that eflow assessment in the Great Ruaha (a sub basin of Rufiji) started in 1993 in the National Park when a 200 km section of the river was drying up. The government committed itself that the Great Ruaha flows would be fully restored by 2010. The study is now complete and the eflow recommended will be implemented. The recommendation included construction of a dam upstream to store water. The report gives a reserve figure (eflow) which has been determined and will assist in guiding revision of allocation in the upper catchment. The plans for IWRM will also take into account this work. The basin is now conducting a study on climate change in the basin with experts from University of Dar Es Salaam and Copenhagen.

The Basin is in the process of moving to the next step of implementing the determined eflow. Monitoring will be an important undertaking during the implementation –river health monitoring is required but there is a need for expertise on how to carry this out. The Basin also needs to make sure eflow monitoring is occurs in an integrated way.

A national water board and basin board has been set up as well as catchment committee and sub-catchment committees followed by water user associations (WUAs). If these institutions will carry out their roles and responsibilities as expected, then the Great Ruaha will be able to flow throughout the year.

Section H: Monitoring issues

Substantial monitoring has taken place and is noted in the projects reported above. Numerous suggestions for future monitoring are also noted, particularly in the WWF report (WWF Tanzania Country Office (WWF-TCO). 2010) which are reported below. However, a routine monitoring programme has not yet been produced, that will secure long-term monitoring for management purposes.

Hydraulics

As the sampling was conducted during medium flows, another sampling programme in low flow seasons is recommended. During the latter season it is expected to adequately capture the micro-topography of the hydraulic controls and critical low flow conditions for the aquatic life.

The hydraulics of the wetland are important for interpretation of where the water goes – this information was found to be elusive despite sound attempts to understand the morphology of the wetland.

Hydrology

Rating information for high flows at the source site (Msembe gauging station), and flow data at the selected BBM sites (both high and low flows), are still needed.

Wetland hydrology information was patchy and scarcely adequate and needs to be upgraded. Various components of the hydrology are recommended for future monitoring. This included the groundwater and evaporation from the wetlands.

Water quality

WQ of the wetland was a decade old and needs to be refreshed.

Geomorphology

Information regarding extreme conditions (extraordinary high flows) is needed in order to determine how often or at what intervals when extraordinarily changes of channel morphology occur.

The geomorphology of the wetland was poorly understood and needs to be updated.

Riparian vegetation

Further sampling is required to gain a more comprehensive understanding of riparian vegetation dynamics with relation to flow.

Fish and invertebrates

Sampling in different flows (wet and low flows in a calendar year) is still required, as well as more sampling (possibly 2 days of sampling spent in one site). This also applies to monitoring of the wetland.

Section I: Successes, limitations and gaps

While there were intitial concerns that the work done to date was not well coordinated and was rather unstructured with a low confidence EF estimation having been done, this has largely been overtaken by the WWF report (WWF Tanzania Country Office (WWF-TCO). 2010). This report describes an excellent project not only to determine environmental flows making use of existing data and also collecting fresh information, but in integrating this into the management of the resource. The process has been thoroughly reasonable throughout and is a credit to Tanzania. All that remains is to effectively implement these recommendations!

1. There is an excellent vision and a number of scenarios that have been developed for the basin. These have been well considered for implementation.

2. There is also a lot of information on how the upstream catchment could be better managed to protect the downstream system. The plans to effect this are well considered and an excellent start.

3. It is clear that implementation of EF in the Ruaha River is well advanced, with wide ranging consideration of how these environmental flows can be included into overall water resources management. This is an excellent start.

4. The development of RQOs is far advanced in that they include both narrative and quantitative descriptions of the resource in a way that is suited to monitoring.

There are a number of limitations associated with this work on the Great Ruaha River and the Usangu Wetland associated with it. These can be summarized as follows:

5. There are a wide range of studies which have contributed to understanding the issue of environmental flows in the Great Ruaha, but all of these have not originated from the same source. While this diversity of interests is a positive attribute, the overall outcome reflects a lack of coordination. To a large extent this has been overtaken by the WWF report (WWF Tanzania Country Office (WWF-TCO). 2010).

6. The model used for the early determination of the environmental flows was the Desktop Reserve Model which has several limitations. These are not noted here as this work has been overtaken.

7. According to the WWF (WWF Tanzania Country Office (WWF-TCO). 2010) report, two further BBM sites should be established, one on the rejuvenated high gradient zone downstream of BBM2, and the other on the braided floodplain section upstream of the Mtera inflow as identified by the geomorphologist during this study and detailed in the geomorphology starter report which is available from WWF TCO and RBWO. The purpose of these further sites is to check that the recommended flows for BBM1 and 2 will also meet the objectives for the river downstream.

8. The SASS average scores computed for the three sites define all of them as slightly impacted which may not a sound conclusion as there is no reference data to peg the SASS according to the appropriate ecoregion.

9. There has not been any detailed evaluation of the sensitivity of the river ecosystem to changes in the nature of the river including its flow.

Way forward

The list of actions were by the WWF study as necessary to restore flows to the GRR (WWF Tanzania Country Office (WWF-TCO). 2010). This is a comprehensive list but will not be presented here, suffice to say that the list is wide-ranging and covers issues of practicality such as repair of a boat, to directions to investigate the socio-economic study.

There is a similar list describing the way forward for the wetland that includes issues such as the control of aliens to the use of water for irrigation. Again this is a valuable initiative as it indicates that management are already using the information from the EF study to implement more effective water management in the basin.

From the point of view of this review, the combination of authorities and researchers from a number of different organizations has worked well to develop an excellent situation for the management of the water resources of the Great Ruaha River including the management of its environmental flow requirements. While at first the collection of reports that was produced appeared to be somewhat disorganized, this has culminated well in the 2010 report by the WWF where much of this information has been brought together. This augers well for the future implementation of an integrated system of water management.

Chapter 5. The Mara River

Section A: Initiation and scope of studies

The Mara basin is different to the other basins studied and reported on in this review, in that it is transboundary. The implications of this are apparent by who is supporting the work done on the various aspects of the water resource management in the basin. Here there is less involvement of national governments, and more of regional and global organizations. Recently the East African Council of Ministers agreed to support the implementation of environmental flows in the basin (Doris Ombara, *pers com*).

Harmonizing the efforts of the different role players, including the national governments, has been the subject of much investigation and reporting. The main intent of this work has been to enthuse the two governments to work together for the best interests of the whole basin, which if successful, would be for the benefit of both countries.

Examples of work carried out that relate to support of governance structures include:

Mara River Basin Policy, Legal, and Institutional Cooperative Framework (NBI, 2008c) a project supported by the Nile Basin Initiative. This project undertook to carry out a legal, institutional and policy analysis for the development of a comprehensive Cooperative Framework for the joint management and development of the shared water resources of the Mara River Basin. It examined the state of existing national and regional institutions, their policies and legal arrangements, and their capacity to cope with challenges associated with the sustainable management and development of the shared water resources of the Mara River Basin. The value of this project is to describe how the legal and institutional structures of the two countries in which the Mara basin lies, can best be harmonized to ensure proper and synchronized management of the system. It identifies the shortcomings in both countries and proposes a way forward.

Biodiversity Strategy and Action Plan (BSAP) for Mara River Basin (LVBC, 2009) - The BSAP was developed on the basis of international, regional and national frameworks on biodiversity conservation. Both Kenya and Tanzania ratified the Convention on Biological Diversity (CBD) and have developed National Biodiversity Strategies and Action Plans (NBSAP) to address the requirements of the CBD. Both countries are also Partner States of the EAC and are parties to the EAC Protocol on Sustainable Development.

One of the key focuses of this BSAP is the protection of the Aquatic Habitats of the Mara River. In recognition of the stresses being faced by the basin, WWF-ESARPO in liaison with the LVBC is pursuing a strategy of using Environmental Flows to determine appropriate water resource allocation in the MRB. The Nile Basin Initiative, under the Nile Equatorial Lakes Subsidiary Action Plan (NELSAP), began the Mara River Basin Project (MRBP) in 2002. This program is also aimed at implementing IWRM in the MRB.

A report on **Assessing Reserve flows for the Mara River (LVBC, 2010)** was authorized and published by the Lake Victoria Basin Commission of the East African Community. It was conducted by the Kenya and Tanzania Ministries of Water and Irrigation, with technical expertise from water resource managers from Lake Victoria South Catchment Management Authority and Lake Victoria Basin Water Office in cooperation with scientists from local and international universities. The undertaking was facilitated by the Global Water for Sustainability (GLOWS) Program and the Worldwide Fund for Nature-Eastern and Southern Africa Regional Programme Office (WWF-ESARPO) with financial support from the United States Agency for International Development- East Africa (USAID-EA).

Scientists from Florida International University and UNESCO-IHE Institute for Water Education have also been conducting research in partnership with scientists from Egerton University, Jomo Kenyatta University and the National Museums of Kenya. These scientists work closely with WWF-MRBMI, NELSAP-MRBP and other implementing bodies in the region, which in turn work closely with local, national and regional water resource management authorities from both Kenya and Tanzania. Other developments include the formation of National Technical Advisory Committees, a Trans-boundary Water Users Forum, National and Trans-boundary Stakeholder Forums, and a Secretariat for the MRB.

In both Kenya and Tanzania, the responsibility for water resource management occurs at multiple levels: national, basin, catchment and local. Both countries have national policies that recognize the importance of the Reserve and call for its protection and consideration in all water resource decisions. They also both have independent regulatory bodies—National Environmental Management Authority in Kenya and National Environmental Management Council in Tanzania—that are not part of any particular Ministry. These agencies can prove invaluable in enforcing the national environmental policies protecting Reserve flows.

In Tanzania, the Mara River and the responsibility for establishing and maintaining the Reserve in the Mara River, falls under the management of the Lake Victoria Basin Water Office (LVBWO) located in Mwanza, in the Ministry of Water and Irrigation (MOWI). They are currently drafting a water resource use and management plan for the catchment to implement Tanzania's Water Resources Management Act (2008), and protection of the Reserve is included in this plan. At the basin level, the Sub-catchment Water Office, located in Musoma, is responsible directly for the Mara River. They are legally mandated to enforce LVBWO's management plan through monitoring and regulation. At an even more local level, water resource use is regulated by a District Water Engineer in the Ministry of Local Government. Each district has developed a Water Master Plan that is approved by the MOWI, and abstraction permits are first applied for through the District Water Engineer.

Transboundary issues related to management of the Mara River and the equitable sharing of its economic benefits between Kenya and Tanzania could be addressed through the Lake Victoria Basin Commission of the East African Community. This effort would also benefit from the participation of the newly formed Mara Transboundary Water Users Forum. Eventually, a transboundary Reserve flow and surplus flow could be agreed-upon by Kenya and Tanzania under the auspices of the East African Community.

There is a long list of projects that have been carried out over the past decade, which operate at a transboundary level, but deal with particular issues related to the Mara basin. Such project objectives have included studies on the hydrology, use of resources, water quality issues and indeed the assessment of the EF requirements. All of these play some role in supporting the assessment of environmental flows, and where this is the case, they are introduced below.

The **Mara River Basin Management Initiative (MRBMI)** is a transboundary project (Kenya/Tanzania) implemented by WWF Eastern African Regional Programme Office (WWF EARPO) in partnership with national/local governments and other stakeholders in the basin. The project is funded by NORAD , WWF-Norway and USAID through the Global Waters for Sustainability (GLOWS) programme. Activities implemented by the project include the documentation of best practices and failures in terms of sustainable management and conservation related to the river. This initiative is the home of the main EF projects to be done that are documented below.

The two key reports in the context of this review are those dealing directly with the environmental flow requirements of the Mara River in both countries – the **Environmental Flow Assessment (EFA), Mara River Basin: Proceedings of the Final EFA Workshop. (WWF-EARPO, 2007)** and **Assessing Reserve Flows for the Mara River, LVBC (2010)**. The project described by these two reports was undertaken by the Kenyan and Tanzanian Ministries of Water and Irrigation and carried out in cooperation with the GLOWS Programme (funded by the U.S. Agency for International Development) and the WWF-EARPO office. The Mara River is a transboundary river shared by Kenya and Tanzania, supporting both biodiversity and livelihoods of people living within the basin. This was the first EFA exercise to be carried out in Kenya and the first to be done on a transboundary river. Following a meeting held in November 2005, it was decided that the Building Block Methodology (BBM)

(King et al. 2008) was the most suitable method for the needs of resource managers in the basin and would be adopted as the method of choice for the Mara River. Three sites referred to as BBM1, BBM2 and BBM3 were sampled. Although only the latter site physically represented Tanzania, all three sites were deemed critical to understanding basin-scale dynamics in this transboundary system.

The LVBC (2010) report was the only one of the several documents reviewed here, that deals directly with environmental flows and is of prime importance. This report makes an important point clear – that "*Reserve flows are not for the purpose of protecting the fish and insects chosen as indicators. Rather, the Reserve is intended to protect the ecological processes and services indicated by the presence of these species, such as degradation of contaminants, breakdown of organic matter and erosion control. These processes are critical not only to the health of the river, but primarily to the health of the human communities that depend on it, many of whom rely on it as their primary source for drinking water.*"

Other projects which have the potential to contribute useful information to understanding environmental flows include:

Tanzania National Parks – UNESCO-IHP Demo site on Mara River and Serengeti Plain, Kenya and Tanzania (WWF-EARPO 2007). The project links the concept of Ecohydrology principles in the use of water to various initiatives taking place within the Mara River Basin. Activities to be completed are a full evaluation of the hydrological balance of the Mara River System and assessing the effectiveness of cooperation/integrated management of water resources in improving water quantity and quality and biodiversity in Mara River Basin. This project works closely with various stakeholders such as World Wildlife Fund (WWF), Kenya and Tanzania in the Mara River Basin, East African Community, Frankfurt Zoological Society, Ministry of Water and Irrigation and various non-government organizations. (Note that the thrust of this project was the large mammal migrations – not the environmental flow requirements of the river).

Kisoyan (2006) reported on a project which has as one of its objectives the "production of scientifically tested strategies to guide policy, regulations, and support systems required for integrated management of livestock, wildlife, and water resources.". However, this project was wide ranging and only touched on EF. What is usefully contained in it though, is the socio-economic and institutional background, and the management of the catchment that will ultimately need to be managed in order to achieve EF in the Mara.

NOTE that there are several other relevant projects, many of which are mentioned in the report below.

Section B: Process to define areas of study and assessment (rivers, estuary, lakes and wetlands)

While there are many studies that have examined water issues in this basin, only the **LVBC (2010) Assessing Reserve Flows for the Mara River** study is considered in this section as this is the only study which exclusively deals with this issue.

Given that this review is considering only research done in Tanzania, emphasis is given to site 3, where the Mara river crosses the National boundary and into Tanzania. Inevitably though, protection of environmental flows in the Tanzanian portion of the Mara will be dependent on upstream catchment issues as well.

Site selection began with geomorphological surveys that classified the river into three uniform macro-reaches based on gradient, channel pattern and bed structure. During initial field visits, the multidisciplinary group of specialists chose a representative site for each macro-reach. The selected sites exhibit fluvial processes characteristic of the macro-reach, as well as represent the interests of multiple stakeholders in the basin. Additionally, these sites incorporate small-scale habitat diversity; as such, all sites were placed on 100 meter-long, straight stretches of the river that included runs, pools and riffles.

Figure 1: Site Map of trans-boundary Mara River Basin and the three study sites used in the Environmental Flow Assessment.

Section C: Evaluation of the original & present state of the systems

There are several reports which document the change in the river ecosystem over time, thus establishing the original condition against which the present is measured. It is not the place for this report to review all of these results other than in general terms related to the process of assessment rather than the results.

Many of these reports refer to the change in hydrology of the river and attribute the decline to the degradation of the vegetative cover in the upper catchment as well as an increase in abstractions.

These studies also refer to the deterioration of water quality in the river.

The LVBC (2010) project describes the Present Ecological State (PES) of the river at the three selected sites, recognizing the natural, or reference condition at each site and including an assessment of how far each site has changed from the reference condition. Sites have been ranked on a scale from A (natural) to F (critical/ extremely modified) and were assigned a Trajectory of Change, indicating whether each component was getting better or worse under the current river management regime. Sites were also classified according to their Ecological Importance and Sensitivity (EIS), indicating their importance for maintenance of ecological diversity and system functioning on local and wider scales, their ability to resist disturbance and their capability to recover from disturbance. Finally, sites were assigned an Ecological Management Category (EMC), summarizing the overall objective or desired state for each site. Sites could be ranked from A (natural) to D (largely modified); categories E and F were excluded from consideration because they were not considered sustainable.

The details of the PES, EIS, trajectory of change, and Ecological Management Category are all documented in the reports.

Also provided are objectives for achieving a particular ecological category for each major component of the river ecosystem, e.g. the discharge required to provide for critical indicator species in the category selected, during February, is provided. The ecological consequences of NOT providing these flows are also documented, although in a way that is rather difficult to follow.

An example of the output of the present state assessment and the recommended category is given below for site BBM 3

Component	PES	Trajectory	EIS	EMC
Fish	A/B	(0)	**Very high**	A/B
Invertebrates	C/B	(0)		B
Riparian vegetation	B	(0)		B
Geomorphology	B	(-)		B
Water quality	B	(-)		B
Overall	**B**	**(-)**		**B**

The PES at all study sites on the Mara was ranked as B, indicating some degree of modification from the natural state but nevertheless the river ecosystem remains in a relatively good condition. All sites were found to be declining under the current management regime. This is cause for concern, as all sites also had a Very High EIS (ecological importance and sensitivity). Pristine conditions are not likely to be achievable in this system given its importance to the Livelihood sector. Thus, an Ecological Management Category of a B was chosen, suggesting that management actions act to maintain current levels of system structure and functioning and to prevent further modification and degradation.

A follow-up assessment was conducted in February 2009 (Subalusky - *pers com*) where a subset of the specialists who conducted the original work were brought back to investigate the situation during critical low flows in the river. The results of this work will be published in the near future. The aim of this additional work was to identify and fill the data gaps from the initial assessment, and to emphasize the importance of ongoing monitoring to ensure recommended environmental flows are adequate.

The above study is being added to by the work of a number of other studies and, in the longer term, could be supported by several proposals for further work that have been submitted to various funding organizations.

Hydrology:

The LVBC (2010) report documented the hydrological situation in the basin. In order to determine historic patterns of flow in the Mara and its tributaries, data were collected from three different river gauging stations on the Amala River at the town of Mulot, the Nyangores River at the town of Bomet, and the Mara River at

Mara Mines. Hydrology data from these sites were extrapolated to fit the three chosen study sites (Sites 1-3). Data were compiled to present historical flow records at different time scales and in wet and dry years. Data were also used to calculate flow duration curves and flood frequency and low flow recurrence intervals. This data indicated the magnitude and timing of flows, and noted that the river has not dried up completely at the study sites in the past fifty years of monitoring. Many of the tributaries, however, do stop flowing during the dry season. Note that no information on the quality of the hydrological data used for this project is provided in this report.

A report by Krhoda (2006) also documented the hydrology of the Mara basin. This report set out to link the hydrological characteristics with options for sustainable use of the water resource. The investigation did not undertake any field work and was limited in its ability to collect and produce information. All information used was in the public domain. One of the objectives of the report was to discuss the impact of upstream water users on downstream users, including requirements for wildlife in the Masai Mara National Reserve and spillover into Serengeti National Park and the biodiversity of the wetlands along the Mara river. This it does but provides only limited information, concentrating mostly on Kenya, with little that is of value to the environmental flow assessment. The basic hydrology is however useful.

A report by Melesse, et al (2008a) Hydrometeorological Analysis of the Mara River Basin, Kenya/Tanzania, part of the GLOWS project, documents the rainfall and corresponding discharge at three sites in Tanzania. They document the basic hydrology of the river, the maximum and low flows, and the monthly flow duration curves. A second paper by Melesse, et al (2008b)) Modeling the Impact of Land-Cover and Rainfall Regime Change Scenarios on the Flow of Mara River, Kenya, noted that hydrometeorological analysis of the basin has shown a decline in the dry season flow and increase peak flood frequency in recent years. Changes in the precipitation pattern (distribution and volume), deforestation in the upper basin and increased water use activity in the large scale agricultural areas upstream is noted as an issue.

In the report Consulting Services for the Assessment and Design of Hydrometric Network and Guidance of Water Quality Survey for Mara River (NBI, 2008a), it notes that at present there are only 2 hydrometric stations operational on the Kenyan side of the Mara River Basin out of 7 stations that have been operated before. On the Tanzania side there are only 2 stations that are operational. This gives a network density of 3500 km^2 per station, which is below the range of norms for a minimum network. In view of the anticipated development in the Mara River Basin, ten river gauging Stations are proposed to constitute the hydrometric network on the Kenyan side, while seven river gauging stations are proposed to constitute a network on the Tanzanian side of the Mara River Basin. This report also provides a detailed assessment of the water quality in the basin, looking at this from a general IWRM point of view and not specifically from an EF point of view.

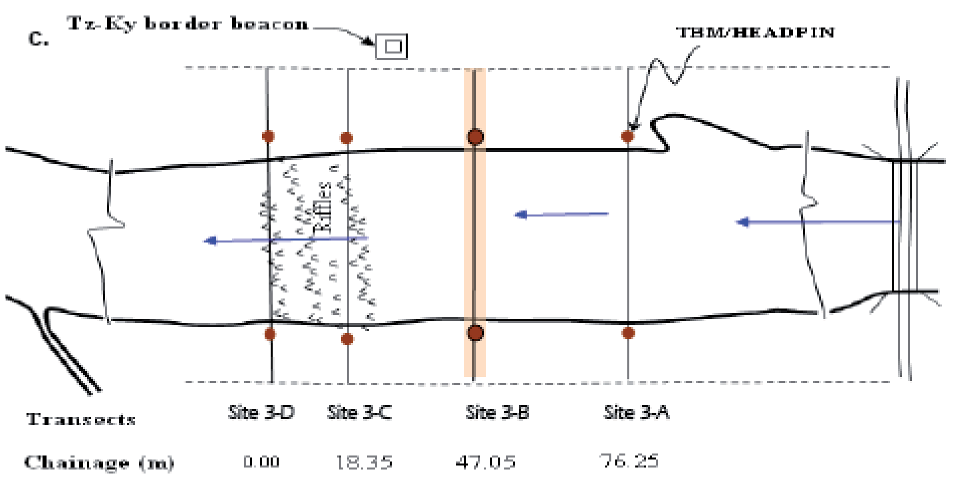
The thesis by Christina Hoffman (2007) Geospatial Mapping and Analysis of Water Availability –Demand-Use within the Mara River Basin published by the Florida International University concluded that the total current water demand within the basin does not appear to eclipse water supply during periods of mean flow. However, the current water demand does pose a threat to water resources within the basin during periods of minimum flow. Most of this report was however, based on the demands for water resources in the basin linked to its availability. This work was done before any estimate of the EF for the Mara was developed, and thus EF principles were only considered in rough terms.

Gereta et al (2009) noted that as a result of various land based activities in Kenya, with business-as-usual in Kenya, the Mara River may dry out for at least one month when a severe drought such as that of 1972-1973 next occurs, and that as a result the Serengeti ecosystem may collapse - more precisely, the wildebeest population would drop 80% from about 1 000 000 to about 200 000 animals. They recommend that remediation measures are urgently needed in Kenya to restore the flow in the Mara River during low flow conditions and, if this does not occur, disaster prevention measures are needed to preserve this ecosystem by providing water in weirs, dams, and artificial wetlands along the Mara River, as well as extending by 5 km the western edge of the park so as to reach Lake Victoria and to provide access to permanent water They note that daily flow rates of the Mara River at Mara Mines during exceptional droughts may have been smaller than 1 m^3s^{-1}. Nevertheless, all eyewitnesses (e.g. park rangers) state that the Mara River has never stopped flowing though the flow apparently reduced to a trickle during the Oct-Nov. droughts in 1972, 1973, 1992, 1993, and 1997.

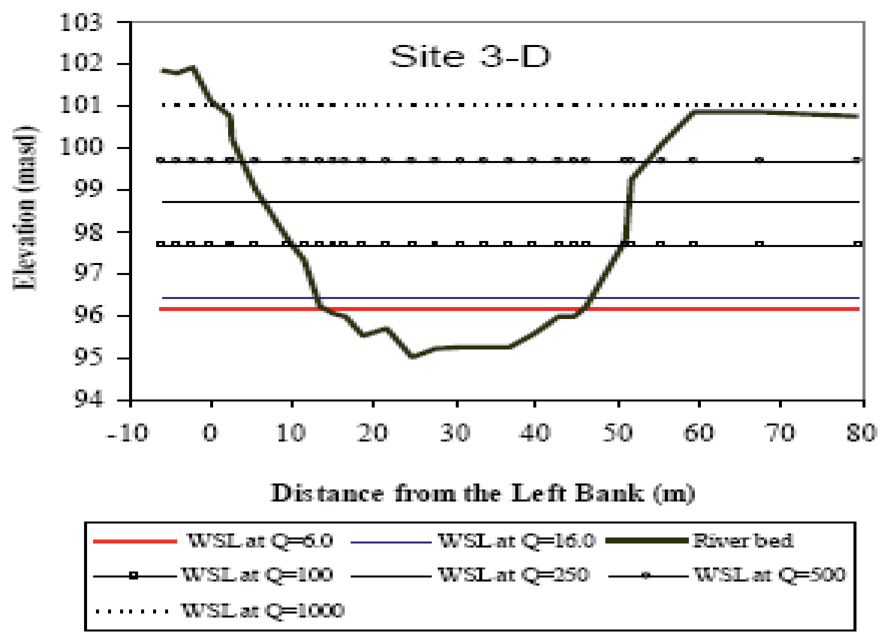
The overall conclusions of the hydrological condition of the river in relation to environmental flows, is that during years of normal rainfall, the EF is met and ample water is available for extractive uses. During drought, the situation may be quite different, with a trend toward unacceptable alterations of the Mara River's flow regime. There is thus cause for much concern if the system is not to degrade to a point where the services from the river begin to fail.

Hydraulics

The LVBC (2010) report provides several hydraulic cross sections which were surveyed at each site, and enables a quantitative assessment of the habitat availability in relation to river discharge to be made. This information is essential if actual quantities of water are going to be attached to the flow requirements of the river ecosystem.



Example figure showing the location of cross sectional surveys at Site 3



Example figure showing the cross section at Site 3D. Different horizontal lines indicate the flow volume (discharge) measured in m^3s^{-1}

The hydraulic information was used to calculate ecologically relevant parameters, such as wetted perimeter and depth. This information is presented in flow graphs such as that below.

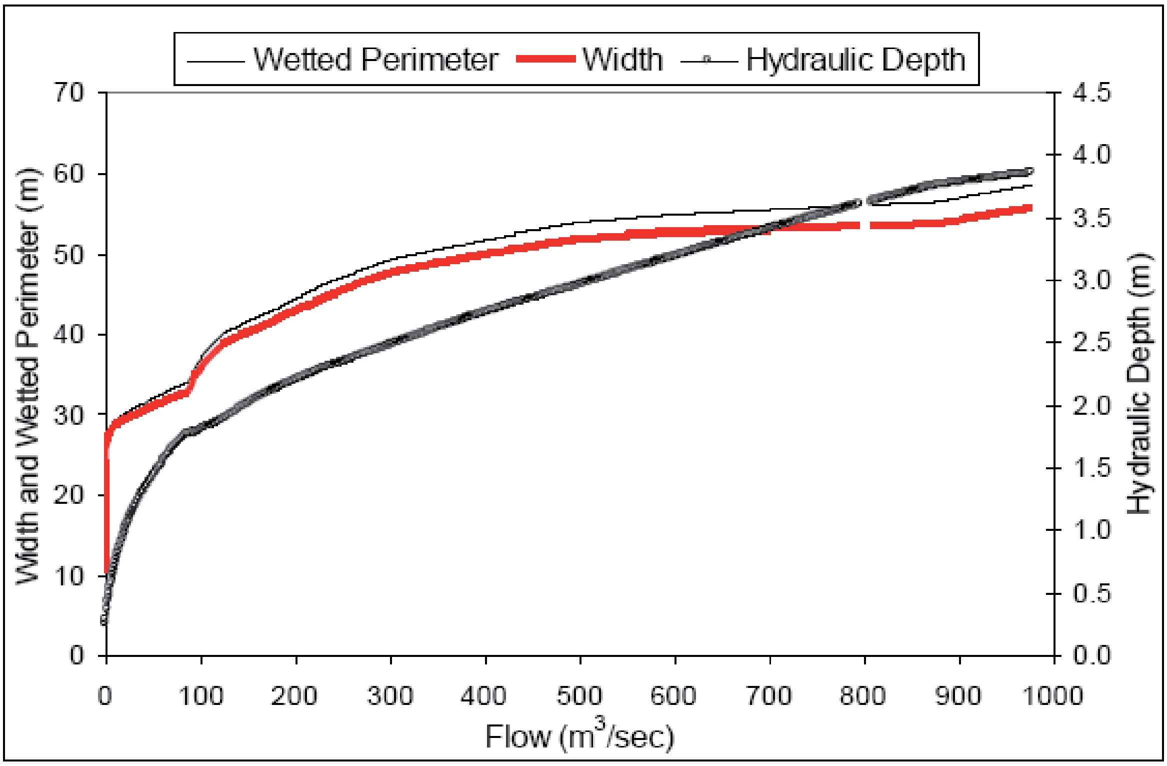


Figure 13: Simulated relationships between key ecological parameters (wetted width, wetted perimeter and hydraulic depth) and discharge at Site 3-D on the Lower Mara. These parameters were used by the ecologists on the EFA team to establish flow requirements for indicator fish, insects and riparian vegetation.

Geomorphology

According to LVBC (2010) at Site 3 both the riverbanks and bed were assessed to be in good condition, although vegetation was sparse and wildlife trails had formed gullies traversing the riparian zone. It was concluded that frequent floods are necessary in both wet and dry years to maintain sandbars, benches and terraces of the active channel. Infrequent but extreme flood events are necessary at this site to maintain the high terraces and floodplain of the macro channel, to transport sediment of larger size, and to reconstruct macro channel features that may have been degraded by external disturbances.

Water quality

In order to evaluate overall water quality in the basin and identify potential threats, a water quality survey was done throughout the length of the Mara River Basin in May-June, 2005 and 2006, and the findings were incorporated into the EFA. Water samples were analyzed for temperature, pH, electrical conductivity, total dissolved solids, salinity, turbidity, total suspended sediments, dissolved oxygen and nutrients. A subset of samples was further analyzed for the presence of heavy metals and pesticides. Flows were recommended in order to maintain high water quality by flushing through of pollutants.

The comprehensive results from this basin-wide water quality assessment can be found in GLOWS (2007). Again, a great deal of the work took place in Kenya and is not always relevant to this project, although naturally the upstream water quality impacts on the downstream river. Also, not all aspects of the work are of relevance to environmental flows, but the report provides a useful source of information for water quality that has been used in the environmental flow assessment.

Of interest is Table 2 of the GLOWS report which documents the Tanzanian Water Quality Standards, and presents five categories of water standards ranked from drinking water to waste discharge. While it is accepted that the environment should not be treated in the same way as a user of water (and impacted by water quality), a water quality standard for protection of the natural ecosystem would be of value and should be included in the list.

List of water quality data collected and reported on the GLOWS report:

- Temperature
- Alkalinity
- pH
- Electrical conductivity
- TDS and salinity
- Turbidity and Total Suspended Sediments
- Hardness
- Dissolved Oxygen
- Nutrients
- Dissolved Organic Carbon
- Mercury and Aluminium (on some samples only)
- Pesticides (on some samples only)

This report concludes that "Increasing water demands in the upper basin in combination with contamination sources also seriously threaten the environmental flows needed to sustain wildlife in Masai-Mara National Reserve, Serengeti National Park, and Mara Wetlands". In this they omit the perspective that environmental flows are needed to sustain the ecosystem in the entire Mara River, not just in the Game Reserves.

A report by Krhoda (2006) documented the hydrology as well as the water quality of the Mara basin. The data presented though is minimal and also old (1990-1992).

In the report by the NBI (2008a) there is detail on a proposed monitoring programme for water quality. This report includes a baseline survey of the water quality on the Kenyan side of the basin, the outputs of which will be of value to the Tanzanian study.

Riparian vegetation

The vegetation component of the LVBC (2010) study aimed to address three primary questions: 1) what important vegetation components are present at the selected study sites; 2) how does that vegetation relate to instream flows; and 3) which species at each site can serve as an indicator of appropriate flow regime? During vegetation surveys, sample plots were systematically placed along transects running perpendicular from the river bed to the edge of the riparian forest. A list of plant species was recorded for each transect, along with species cover, abundance, height and structure. Vegetation zones along the transects were classified according to dominant plant species. The list of species and their horizontal distribution across the channel were analyzed by a classification approach, yielding information on the natural flow regime of the river.

At Site 3, it was determined that maintenance flows and flood events are important to foster recruitment potential and sustain appropriate density and age structure of important species. At all sites, maintenance flows are necessary to recharge the groundwater table in order to sustain woody species. Maintenance flushing floods are critical to maintain marginal vegetation species for bank integrity and to enhance seed germination and dispersal.

Invertebrates

The survey of invertebrates at Site 3 showed some deterioration (LVBC, 2010), with a substantial change in sensitivity score and a reduction of the number of taxa to 7. Because this site was located within the protected areas, human impacts were minimal; however, upstream degradation continued to impact these downstream locations. Target flow-dependent species were identified and their flow requirements determined, both at low flow and higher flow conditions.

Fish

Fish were sampled in surveys at each study site (LVBC, 2010) using gillnets placed in all available river habitats (i.e., riffles, runs and pools) and number and abundance of species, length and weight of individuals, and reproductive condition determined. Fish species were characterized according to their environmental guild, a classification system that groups species that respond similarly to changing hydrology and geomorphology. The flow requirements of the fish species were thus determined.

Additional work describing the fish in the Mara, in this case the lower section of the river, included that by Chitamwebwa, (2007) Baseline Survey of Fisheries Resources in the Mara Swamp and Musoma Bay, Mara River Basin, Tanzania. Reports such as this provide added information for determination of the EF for the entire river, including the Mara Swamp and Musoma Bay.

Socio-economic situation

Data on population growth and increasing water demand were collected (LVBC, 2010). Surveys and interviews were conducted in communities dependent on the Mara River to determine the primary resources and services the Mara River provides. Participants were asked to rate the importance of those resources and also to identify current anthropogenic threats to the river ecosystem.

Based on projections of population increase in the Mara Basin, meeting the minimum needs of people in the basin will require only a small fraction of river discharge and are accommodated by the larger flows required to protect the ecosystem and Reserve flow. This may not always be the case in smaller rivers and tributaries.

Documented in a report by Munishi (2007), the existing biodiversity of the Mara River swamp presents a variety of benefits to the communities adjacent to the swamp. These benefits accrue from utilization of this biodiversity for various purposes including domestic consumption as well as trade that can either be inter-household trade or distant trade to various parts of the districts. The total biodiversity benefits accruing from agricultural crops and other wetland products per person were estimated. A great deal of information is provided in this report, documenting the economic value of the Mara Swamp system. This is useful in establishing the need to provide EF in the Mara.

A report "Mara River Basin Monograph (NBI, 2008b)" documents in great detail the *status quo* of the use of water resources in the basin. This ranges from water supply and sanitation, to agricultural use, fisheries, hydropower and environmental issues. Much of this information will be of value to understanding the situation of environmental flows, and will assist with the implementation of measures to manage the flows.

Section D: Evaluating the importance and sensitivity of the systems

A number of reports have been published which document the importance of the Mara River and Basin for the peoples of Tanzania and Kenya. These provide useful context for the imperative of proper management of the river system. Some examples are:

According to Kisoyan (2006) and quoting widely from the work of Mutie et al (2005), the Mara watershed, straddling the Kenya–Tanzania border, is critical to the survival of pastoralists, farmers, fisher families and wildlife in the Mara-Serengeti ecosystem. It faces growing threats. The forested part of the Mara Basin has decreased from 752 km^2 in 1973 to 493 Km^2 in 2000. This forest cover reduction in the headwaters has reduced the base flow and water quality in the river. They discuss the involvement of stakeholders and government in management of resources and note that a lack of regulatory government mechanisms and low capacity of key stakeholders in natural resource management has contributed to the current state of ecosystem degradation and the inequitable distribution of resources among the communities in Mara River basin.

It is widely noted that the Mara supports some of the highest levels of both species diversity and biomass of large herbivores in the world and is important internationally, regionally and nationally. The migration of large herbivores reaches the Mara River in July or August and continues northward, eventually crossing the border into Kenya's Masai-Mara National Reserve in September or October. This migration has been linked to water availability and water quality. During severe droughts, which occur every six or seven years, even pools dry up, leaving the Mara River as the only perennial water in the region, essential for the survival of the migrants. According to Gereta et al. (2009) the flow rate of the Mara during a drought has decreased by 68% since 1972 and modeling suggests that the Mara River would now dry out during drought years, leading to catastrophic collapse of herbivore populations. It is thus necessary to restore the natural hydrology of the Mara River in Kenya, and this requires remediation measures in Kenya.

The Mara Swamp is an integral part of a large and important fisheries industry which is dependent on the inflows from the Mara. Continued outflow of services from this system requires an input of flows from the Mara River, which highlights the importance of maintaining EF.

At a superficial level, the Mara provides critical in-channel and riparian habitats to a host of animals. There are two primary aquatic habitats, the Mara River itself, and the Mara Swamp. These habitats are linked in a continuous network extending from the headwaters of the basin in the Mau Forest through the Mara Swamp to Lake Victoria. They include channels and adjacent riparian habitats which are heavily dependent on the water and the flow regimes provided by the river.

The importance and sensitivity described above is generally related directly to the maintenance of goods and services for society. Unfortunately there are many other services provided by the river which are possibly even more important than those discussed above, but because they are not as obvious, may not gain the same level of support. For this reason, it has become an accepted norm that the importance of the ecosystem in its own right needs to be established, even if the provision of environmental services is not so obvious. Thus, in the management of a river, the importance of the ecosystem, as an ecosystem, needs to be established.

There has unfortunately been little consideration of the importance of the Mara River ecosystem in this way, considering the species that it contains, the rare and endangered species, the ecological process that underlie the workings of the ecosystem, the role in maintaining channel form, in cleaning up polluted water and processing organic contaminants, the importance of the in-channel and riparian habitats etc etc. Are these ecosystems important on a local, regional and international scale – understanding of which would lend context to efforts to maintain them? There is then also little consideration of how sensitive and resilient these ecosystems are all to stresses imposed by utilization of the resource.

A sentiment expressed in the report by Chitamwebwa, (2007) states that *"in co-management of resources, which takes into account the interests of every stakeholder, a fish species becomes of conservation significance if it is important to the stakeholders. And for local communities, they would pay attention to the conservation of a given species if it is profitable to them either as food or as an income earner. Thus all currently exploited species from the bay and swamp are of conservation significance since they are of value to the communities"*. While this view is true at a level and does at least acknowledge the relationship between the ecosystem and the value to society, leaving the judgment of this to stakeholders is fraught with dangers, as stakeholders do not always appreciate the provision of services from the ecosystem, mainly because they do not understand what is being provided to them. For example, can rural stakeholders understand the value to them of a carbon sink offered by a peat swamp? Do they understand the value of benthic invertebrates in purification of water of organic pollutants? Stakeholders often have a biased and short term view on the provision of these services, and thus cannot be relied on to be arbiters of what needs protection. It is thus strongly recommended, that a proper evaluation of the importance and sensitivity of the Mara River ecosystem is carried out. New initiatives are presently under way under the MaraFlows programme that will provide additional information that will address some of these issues (UNESCO-IHE: Institute for Water Education. 2009). The project addresses the overall objective of *understanding better the relationships between the flow regime of the Mara River Basin and aquatic ecosystem processes that maintain water quality in the river channel and the productivity of papyrus and select fish species in the Mara Wetland*.

Section E: Quantifying the environmental flow requirements

A standard approach as outlined by the BBM method for determination of environmental flows was followed for the three sites on the Mara River. This has been summarized in the two reports – the Environmental Flow Assessment (EFA), Mara River Basin: Proceedings of the Final EFA Workshop, (WWF – EARPO, 2007) and Assessing Reserve Flows for the Mara River (LVBC, 2010), which can be summarized as follows:

> The EFA Team met in October, 2007, to determine the flow regime needed to meet the Resource Quality Objectives (RQOs) of the river. Each specialist presented the necessary flow requirements for his or her component of the river system for each of the environmental flow building blocks. Specialists explained their motivations for all flow requirements and described the potential consequences of not meeting the requirement. During the process, a consensus was sought among the specialists of the minimum flows and floods that would suffice to achieve the RQOs. Based on the specialists' recommendations for average flows during key months of the year, the hydrologist extrapolated these recommendations across the entire year in a manner that simulated the natural shape of the river's historical hydrograph. The modified hydrograph, with associated floods, serves as the recommended Reserve flow. These Reserve flow recommendations were compared with the historical hydrograph for each site in order to determine the amount of water available for extractive use.

At Site 3 on the border between Kenya – Tanzania and Masai Mara National Reserve – Serengeti National Park, the Reserve accounts for, on average, 35% of the average monthly flow recorded over the 26 years of available flow data from the nearest gauging station.

It is important to note, however, that the percent of flow held in the Reserve varies over the course of a year, mirroring the natural highs and lows of the system. The majority of water available for abstraction is therefore concentrated in a few months when flows are high. Far less water is available for abstraction during dry season months.

Biotic requirements

The two reports (WWF – EARPO, 2007 and LVBC, 2010) that document the EF for the Mara River, present the results of a number of biological requirements for river flows. These are usefully presented, separately for each taxon, noting the discharge, duration and timing that is needed to sustain that particular taxon. This follows detailed assessments of the present state of the ecosystem and of each biotic indicator, as presented above.

Environmental flow requirements

The chief outcome of this project is a table of flow requirements for the months of the year to sustain the river ecosystem. This table is presented below.

The observation that drought year reserve flows are not being met in the upper and middle reaches of the Mara may be the first clear evidence of a trend toward unacceptable alterations of the Mara River's flow regime. Upstream impacts are necessarily linked to downstream resources, and poorly managed water abstraction above the wildlife reserves will ultimately affect the downstream reaches as well. Furthermore, the Reserve estimates in this assessment have not taken into account the environmental flow requirements of the Mara Wetland, which may be different. The Reserve also does not include flow volumes necessary to meet the extractive water needs of Tanzanian communities and industries between Serengeti National Park and the Mara Wetland. Thus, flow levels reaching Tanzania must be high enough not only to sustain the Reserve but also to meet Tanzanian extractive needs.

Table 10: Environmental flow requirements for Site 3 in the lower Mara River Basin. FDC- Flow Duration Curve; MCM- million cubic meters; MAR- median annual runoff.

Building Blocks		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Maintenance EFR Base Flows	Magnitude (m^3/s)	6.1	6.0	7.9	15.0	15.0	9.4	6.6	6.8	8.2	6.0	6.9	6.1
	Depth (m)	0.6	0.6	0.7	0.9	0.9	0.7	0.6	0.6	0.7	0.6	0.6	0.6
	Volume (MCM)	16.5	14.5	21.1	38.9	35.6	22.3	18.9	19.2	20.7	16.4	18.8	18.2
	FDC % present	66%	67%	60%	37%	37%	55%	64%	63%	59%	67%	63%	66%
Higher Flows	Magnitude (m^3/s)				90	25	25	25					
	Depth (m)				1.8	1.1	1.1	1.1					
	Duration (d)				3	2	2	2					
	Return Period (y)				1	1	1	1					
	Volume (MCM)				23.3	4.3	4.3	4.3					
	FDC % present				3%	19%	19%	19%					
Drought EFR Base Flows	Magnitude (m^3/s)	2.4	2.0	2.4	4.2	6.0	4.3	3.9	4.2	4.5	3.4	2.5	2.7
	Depth (m)	0.4	0.4	0.4	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.4	0.4
	Volume (MCM)	6.4	4.8	6.4	11.0	16.1	11.1	10.4	11.2	11.7	9.0	6.4	7.1
	FDC % present	83%	87%	83%	73%	67%	72%	74%	73%	72%	78%	82%	82%
Higher Flows	Magnitude (m^3/s)					20							
	Depth (m)					1.0							
	Duration (d)					2							
	Return Period (y)					1							
	Volume (MCM)					3.5							
	FDC % present					27%							

Maintenance EFR	Base Flows	Higher Flows	Total	**Drought EFR**	Base Flows	Higher Flows	Total
Volume (MCM)	260.9	36.3	297.2		111.5	3.5	115.0
as % of MAR	46.2%	6.4%	52.6%		19.7%	0.6%	20.3%
MAR (MCM)	564.92						

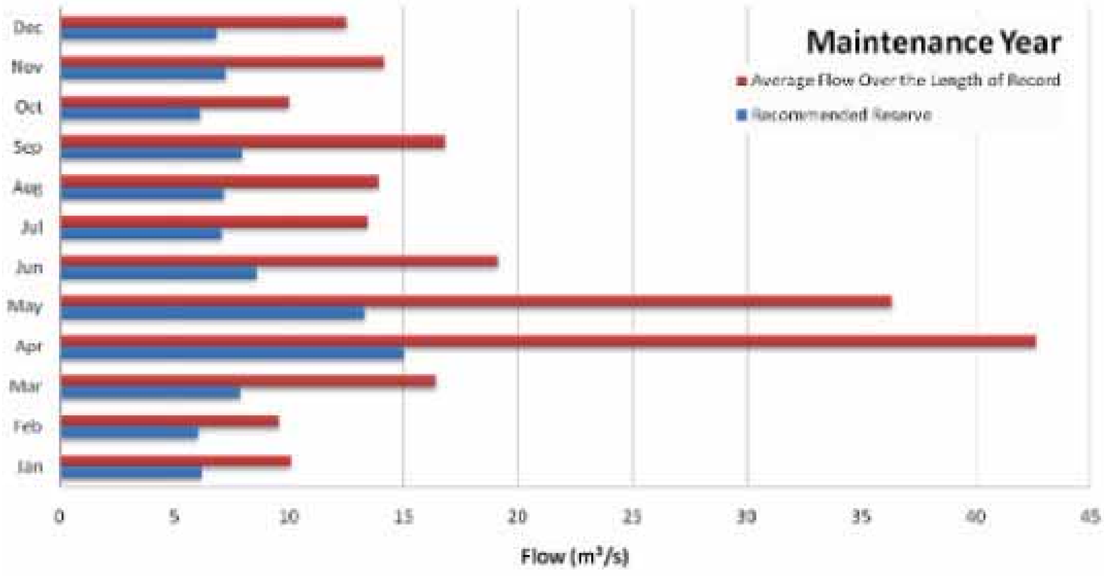


Figure for Site 3 summarising the flow requirements for a maintenance year.

Section F: Setting a vision for the river basin and development of scenarios

The legislation of Kenya and Tanzania both give context for the setting of a vision for the Mara. In Tanzania, the Water Resources Management Act (2009 Part VIa. Water Resources Classification and Reserve) provides for protection of water resources which includes water resources classification and reserve. This includes that the Minister can Gazette the classification of a resource, specify the resource quality objectives of the class to which the resource belongs, and the requirements for achieving these objectives. There is thus a clear requirement to set a class to which the resource should be managed and to describe this by way of resource quality objectives.

Other initiatives have also described visions for the basin which could be synchronized with the above legislative requirement: the goal for the Biodiversity Strategy and Action Plan (BSAP) for the Mara River Basin (LVBC, 2009) is based on the shared vision of the Lake Victoria Basin which aims at having: "A Prosperous population living in a healthy and sustainably managed environment providing equitable opportunities and benefits". Also the overall Goal for MRB is to have "a region rich in biodiversity which benefits the present and future generations and ecosystems functions".

The objective of the BSAP for aquatic habitats is to improve water and other aquatic resources management in the basin, and to balance resource conservation with resource use and development through the following specific objectives:

a) Prevent or mitigate land degradation in order to minimize sediment and organic pollutant loads;

b) Promote improvement in water management schemes;

c) Enhance linkages for improved water resource management;

d) Utilize natural fish stocks while sustaining the biodiversity of the water bodies;

e) Utilize fish farming for protection of endangered fish species and biotopes; and

f) Mitigate and avoid negative impacts of fish farming.

The BSAP provides a number of activities designed to meet the objectives for Aquatic Habitats (LVBC, 2009). A sub-set of those that have relevance to environmental flows include:

Objective (a): Prevent or mitigate land degradation in order to minimize sediment and organic pollutant loads.

iv. Establish and implement the Reserve Flow to ensure that water needs of habitats and species are met;

viii. Monitor water quality, quantity and impact of sediment and organic pollutants on biodiversity.

Objective (b): Encourage improvement in water management schemes

vii. Conduct a full evaluation of the hydrological balance of the Mara River System;

Objective (d): Utilization of natural fish stocks while sustaining the biological diversity of water bodies.

xii. Develop monitoring indicators of aquatic biodiversity and include them in the MRB monitoring program;

Objective (e): Application of fish farming for protection of endangered fish species and biotopes.

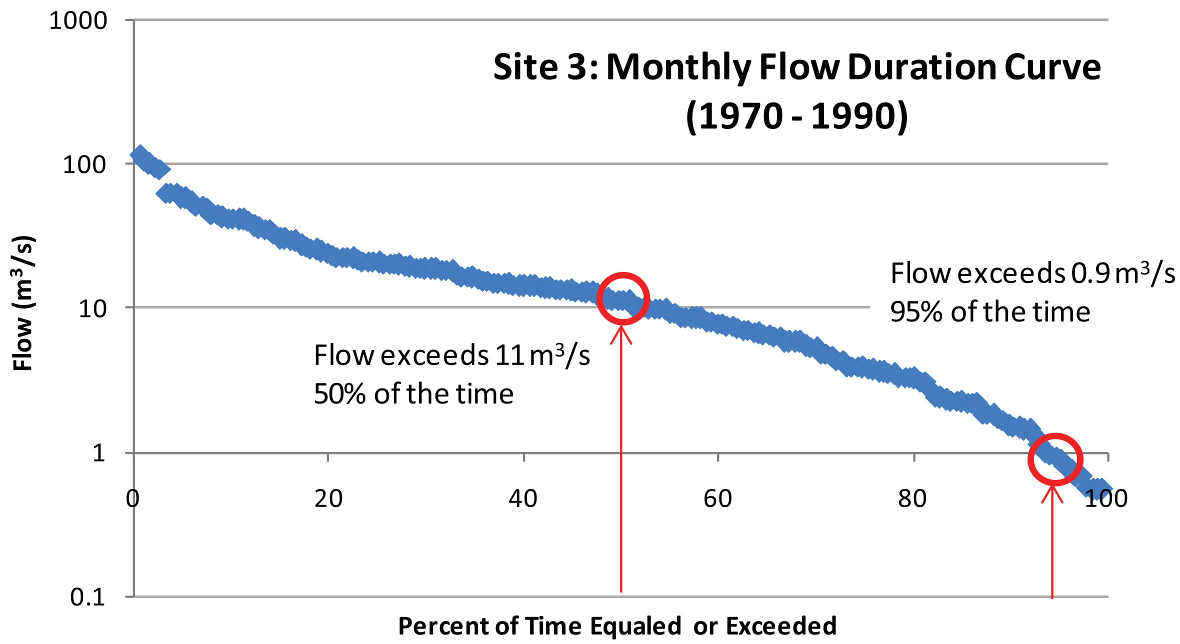
iv. Undertake an inventory of the fish community and their environmental needs;

vi. Create a database and monitoring plan for introduced and invasive fish species.

The water quality report (GLOWS, 2007) documents a Vision for the Mara basin that has been developed in conjunction with stakeholders. This vision makes reference to environmental flows *"Water allocation decisions are based on accurate knowledge of environmental flows, and allocations are guaranteed to support the renowned natural ecosystems of the basin, including the Mau Forest, Mara-Serengeti ecosystem, and Musoma swamps of Lake Victoria"*.

The project supported by the Nile Basin Initiative (NBI, 2008c), Mara River Basin Policy, Legal, and Institutional Cooperative Framework, provides a number of scenarios for the development of policy by the two countries, and on how the transboundary water management could be facilitated. These include; Maintain the *status quo*; Bilateral agreement between Kenya and Tanzania; Arrangement under the East African Community; a Management scheme under the NBI; a Hybrid of the EAC and NBI schemes. The project notes that it is up to the two countries to agree on an appropriate approach.

While the above statements provide context for maintenance of EF, they do not actually provide a measurable objective. One such objective is noted in the LVBC (2010) report i.e. the default standard for determining the Reserve in Kenya (this does not appear to have been stated for Tanzania and is now regarded as being largely outdated and due to be replaced by EF estimations (Doris Ombara *pers com*)), is the flow level that is exceeded 95% of the time, or Q_{95} (LVBC, 2010 – see the duration curve below). According to this report, Q_{95} levels are often very low flows that may be unable to sustain many components of a healthy ecosystem. This type of standard has been used internationally in data poor situations where there is no supporting information but this one is certainly not conservative as it should be. It is recommended that the reserve should rather be estimated as outlined in the BBM approach which has indeed been followed in this study, and that a "standard" such as the Q_{95} may not be a useful objective to use. Hopefully this type of approach will become a thing of the past.



The main objective of the Mara EFA was to determine the necessary Reserve for the Mara River, as defined in the Kenya Water Act (2002) and Tanzania Water Resources Management Act (2009), from near where the river exits the Mau forest to the protected areas of the Serengeti-Mara Ecosystem. This included the setting of Ecological Management Categories for each site i.e. the category towards which the site should be managed. The determination of these categories was done on a purely ecological basis, and represents a category which the ecologists on the team feel would sustain the river ecosystem and would not be an unreasonable objective to implement. Unfortunately what this EMC does not do, is take into consideration all of the other demands on the system, which may make this EMC unreasonable. A process to determine the needs of all stakeholders and the wider basin requirements, needs to be included in this process.

Scenarios for the basin

There are a number of initiatives that portray possible futures for the Mara and include information on obstacles and possible paths to improving the situation in the basin. There is however, no initiative which directly seeks to describe possible future scenarios for the basin in a way which would allow government to make a choice on the direction that management should take. However, WWF, under the GLOWS program and with funding from USAID/East Africa, is in the process of developing a Strategic Environmental Assessment (SEA) which aims to do exactly this (Subalusky, *pers com*). The SEA will build upon the recommendations of the BSAP and EFA to identify different development scenarios in the basin for the purpose of assisting with planning and sustainable development in the basin. This report should be completed by early 2011.

Section G: Implementation of environmental flows

The EF for the Mara have only recently been described, so implementation of those findings is in the early phases. However, the findings and recommendations of the EFA have been adopted by the EAC Sectoral Council of Ministers and recommended for implementation in Partner States. In following with this recommendation, there is one major regional initiative under the umbrella of the EAC that has been designed and is ongoing with the express focus of implementing the recommendations of the EFA report. There are also several other programs which have been ongoing, which were originally conceived to contribute to the protection of environmental flows. Those programs have now been strengthened by the specific recommendations of the report. Some of these initiatives are described below.

The Mara River currently has no major dams acting to significantly modify its flow regime. Thus, flow prescriptions must be achieved by improving management of the catchment and controlling permits for abstractions. The unequal distribution of flows throughout the year also poses the challenge of developing and implementing sustainable technologies for harvesting and storing wet season runoff for consumptive use during dry months. Specific recommendations for the implementation of Reserve flows are as follows (LVBC, 2010):

1. Implement a comprehensive monitoring system on the Mara River to enable daily monitoring of the flow levels at multiple points in the basin

2. Improve monitoring of permitted and non-permitted abstractions to reduce illegal abstractions and to develop an estimate of current abstraction levels

3. Develop a system to easily communicate to water permit holders the current state of the river and the implications for their permitted abstraction amounts

4. Build capacity among water resource managers to consider Reserve flow requirements in all water resource permitting in the basin

5. Build capacity among water users in the basin in regards to the importance of maintaining Reserve flows, implementing soil and water conservation practices and reporting illegal abstractions

6. Develop sustainable methods of harvesting and storing wet season flows for consumptive use during dry seasons

7. Improve soil and water conservation practices in the upper catchment in order to improve dry season low flows

8. Continue to monitor the river's flow levels and ecological health in order to refine Reserve flow recommendations

Bhat et al 2010 (2010) conducted a project *Payment for Watershed Services in the Mara River Basin.* In recent years, water resources management worldwide has started to shift from top-down type of regulatory management towards a governance regime that embraces the role of stakeholders in managing their own resources. A logical suggestion that has surfaced recently is that the downstream users pay for the costs of adoption of best management practices upstream so that there is adequate and constant flow of water in the basin for their benefits as well as incentives to the upstream communities to manage and provide more water and of good quality. Upstream communities in this context become sellers of environmental services while the downstream users become buyers. This financial scheme is popularly known as the Payment for Environmental Services (PES) and has potential to change the way that environmental flows could be implemented. This project comprises a series of studies by FIU professors and students in cooperation with WWF, led and summarized by Dr. Bhat. The studies and resulting implementation plan are being implemented by WWF-ESARPO through the GLOWS program with funding from USAID/Kenya and USAID/East Africa. The implementation plan should be completed by the end of 2010 and they hope to have a MOU in place between potential buyers and sellers by 2011 (Subalusky, *pers com*).

A report by Aboud et al. (undated) also provides information, but only from the basin in Kenya, that will contribute to resolution of the management issues needed to protect EF in the Mara river. They provide a proposal for an integrated management plan to manage the resources of the Mara. In this they document the causes of degradation of the water resources of the basin and the consequences of these threats if left unattended. These consequences provide information and fuel to adopt a proper strategic management approach in order to prevent them from happening. They state that the development of an integrated water resource strategy in the Mara drainage basin would be based on the following premises:

- that conservation of natural resources in the basin should not be in conflict with the socioeconomic needs and interests of the people, since the major economic activities are dependent on the maintenance of high levels of ecosystem health;

- that watershed management in the basin and a sustainable water development strategy can only be achieved through stakeholder analysis, involvement, genuine partnerships and networking, and empowerment of resource users to plan and manage their resources;

- that the strategy should aim at instituting a process of strengthening all stakeholders, and instituting reform processes that will encourage sustainable resource utilization in the basin;

- that the strategy will aim at strengthening and build capacity of communities as one of the stakeholders, based on appropriate and sustained natural resource management.

A project supported by the Nile Basin Initiative **"The Mara Investment Strategy (NBI, 2008d)"** had as its objective is to promote environmentally sustainable socio-economic development of the Mara River Basin through identification and implementation of appropriate investment programs aimed at addressing the critical water resources issues and challenges in the basin. This information would be of value to the implementation of environmental flows. Three of its investment programmes, that would be relevant to EF, include (1) The Mara River Basin Integrated Water Resources Management Program and (2) The Mara River Basin Water Security Programme and (3) The Mara Basin Environmental Management Program. The first describes that it is important for the two countries to adopt an IWRM approach to ensure sustainable management and development of the shared Mara basin water resources. This will ensure rational and objective allocation of the scarce basin water resources among competing (and often conflicting) water uses without compromising environmental quality. The program will also support the development of appropriate management instruments and technical tools required to support decision makers in the planning, management and allocation of water resources to competing water uses in the basin. The Water Security Programme aims to undertake a comprehensive survey of the water resources situation in the basin including the users of the water. This programme should thus consider environmental flow requirements as an integral part of this, especially as this is required by both Kenyan and Tanzanian law. The third programme on environmental management does not address environmental flow issues but concentrates on pollution, forest management and wetlands. The project identified a long list of potential projects to address the above, but unfortunately none of these was specifically related to environmental flows.

Improved management of water and biodiversity resources in the MRB requires trans-boundary coordination, consultation and agreement among the stakeholders. Although tremendous work has been done by the TWB-MRB WWF project, such as Environmental Flows Assessment (EFA), Biodiversity Action Plan (BAP), Strategic Environmental Assessment (SEA) and capacity building of key stakeholders, as well as the work of other implementing partners such as NELSAP, significant challenges still remain in the implementation of the study recommendations from a trans-boundary perspective. To address these challenges, a high-level, regional program was designed by USAID/East Africa and the East African Commission, to implement the recommendations of the EFA through the LVBC.

The LVBC is an apex institution of the EAC legally mandated to represent the five partner states of the EAC and responsible for the sustainable development of the Lake Victoria Basin. The commission is the most appropriate institution to take up the next steps towards implementation of the EFA, BAP and SEA recommendations. Both the BAP and EFA reports were adopted by the LVBC Sectoral Council of Ministers in May, 2009, as critical documents for the management of the basin. The EAC and the LVBC, substantially supported by USAID, produced a work plan to guide the implementation of the **Sustainable Development of the Mara River Basin Project Work plan, (EAC – LVBC. 2009**). The project is funded by USAID EA, coordinated by LVBC and implemented by key stakeholders in Mara River Basin. The work plan provides the framework for stakeholder collaboration in implementation of the project objectives. This work plan has been developed through a consultative process which involved LVBC, WWF, Serengeti National Park, Maasai Mara National Reserve and FIU.

The overall object of the project is to promote harmonized Mara River Basin management practices for sustainability. The project seeks to achieve the following specific objectives:

1. Promote trans-boundary management framework for Mara River Basin

2. Improve protection and management of Mau forest resources and Mara riverine forests

3. Promote improved management of protected areas of Maasai Mara and Serengeti ecosystems

4. Improve water resources management in the basin

5. Institutional capacity building of the Lake Victoria Basin Commission to undertake its regional mandate

Objective 4 (above) included "Water in Mara River is the driving factor to socio-economic development and biodiversity conservation. Whereas the demand for water is increasing its quality and quantity is decreasing. To manage water allocations for socio-economic development and biodiversity conservation; Environmental Flows were established to ensure availability of water for sustaining ecological processes. This objective aims at establishing mechanism to implement the Environmental flows recommendations across the two countries. It is expected that environmental flows concepts will be understood and agreements put in place amongst stakeholders to maintain Reserve Flows".

The proposed strategy is that the LVBC will convene a special training to inform the water resources management authorities at the national and basin/catchment levels across the two countries on environmental flows concept and its application. The LVBC will spearhead consultations aimed at establishing water monitoring guidelines and signing of agreements to ensure data are properly and systematically collected, analyzed and shared for effective allocations of water resources and its management in the MRB. LVBC will build on and scale up the WWF initiative at sub-catchment levels by engaging a consultant to develop the Mara river basin water catchment management strategy.

Relevant major activities that have been indentified include:

4.1 Facilitate development and implementation of Mara river basin water catchment management strategy

Sub-activities

a) Engage consultant to develop Mara river basin water catchment management strategy

b) Convene consultative workshop/s to validate the strategy

c) Facilitate the consideration of the Trans-boundary Water Users Forum (TWUF) by LVB Sectoral Council of Ministers

d) Strengthen/empower the Trans-boundary Water Users Forum to implement Mara river basin water catchment management strategy

4.2 Monitoring of water flows

Sub-activities

a) Harmonize water flow parameters across the basin and standardized schedule of water monitoring (agreements/MoUs)

b) Facilitate the signing of agreement for water quality and quantity monitoring

1.5 Facilitate dialogue with national decision makers about the Reserve Flow

Sub-activities

1.6.1 Convene regional meetings to discuss recommendations of EFA

1.7 Capacity building on the Reserve Flows

Sub-activities

1.8.1 Carry out training and awareness to key stakeholders to understand the EF concept and its application

Deliverables

a) Mara river basin catchment management strategy developed by September 2010

b) Trans-boundary water monitoring parameters and schedules standardized, agreement developed and signed by September 2010

c) Knowledge based on the Reserve Flows enhanced, adopted and monitored by September 2010

The **Transboundary Water Users Forum Work-Plan (WWF, 2009-10)** of the WWF, supported by USAID, includes a description of the possible role of a thirty member forum (made up of government and stakeholder representatives from both countries) which has a mandate to take the lead on transboundary water issues of the internationally shared Mara River Basin. The forum will ensure joint management of the basin, through promoting, coordinating and facilitating sustainable water resource management, and will push for integrated water resource management. Their responsibilities are to undertake all issues that will harmonise the management of the Mara River including those aspects that surround EF. It was specifically stated that they would be *"Taking role in implementing recommendations of biodiversity action plan, environmental flows assessment and strategic environmental assessment"*.

The LVBC and TWUF have some degree of overlap in their work plans, because the two bodies play different roles in the basin. The LVBC is a coordinating institution, with the mandate to coordinate sustainable development in the Lake Victoria Basin. The TWUF is an implementing body comprised of relevant stakeholders and actors in the Mara. Ultimately, the TWUF is envisioned to be a body through which the LVBC can work in the Mara Basin. However, it is critical that specific roles be defined moving forward. Some of the objectivities and strategies of the TWUF relevant for EF are documented below (WWF, 2009-10).

Objective 4.2: Awareness creation for application of Environmental Flows as tool for water allocation and monitoring

Within the recent past several studies have been undertaken within the Mara basin with various organizations such as WWF, USAID, FIU and the information obtained in these studies are crucial, in undertaking integrated water resources management of which is of major interest to the Forum. One such study is the Environmental Flows Assessment that shows the reserve levels within the Mara River that should support its ecological functions.

Proposed strategy

To achieve the above the Forum will approach the relevant authorities involved in water resources management in both the riparian countries to adopt the EF concept when allocating water permits and when doing apportionment. In this case it will lobby the Ministries of Water and Irrigation in both Kenya and Tanzania and other relevant stakeholders dealing in water resources management within the basin.

Steps/Major activities

To achieve the above the Forum will carry out the following:

Carry out basin wide awareness campaigns on EF concept within the basin.

Sub-activities

- Organize awareness creation workshops to various stakeholders and players within the water resources management sector within the basin
- Disseminate EF concept information
- Establish Transboundary EF monitoring unit to keep track on implementation levels
- Organize exchange visit to learn and share experiences on EF within the transboundary users themselves and also other basins with similar initiatives.

4.2.2 Identify gaps in the existing water policies and propose necessary changes

Sub-activities

- Advocate for formulation and adoption of sound water policies.

Deliverables

Awareness creation for application of Environmental Flows as tool for water allocation and monitoring within the Mara River Basin is done.

Relevant water policies reviewed, gaps identified and necessary amendments made where necessary and possible.

Another initiative, although in the upper Kenyan part of the basin, that could ultimately have a significant impact on the management of EF in the Mara River, and include various aspects of water resources management and represent an attempt to bring management of these resources into line with sustainable use, include the Sub-catchment Management Plan (SCMP) for the Amala and Nyangores Drainage Basins (Initiative Consultants, 2010).

Resource Quality Objectives

The Kenyan Lake Victoria South Catchment Management Strategy identifies Resource Quality Objectives (RQOs) for each of the catchment's major river basins. These RQOs are determined according to natural hydrological boundaries, social and economic development patterns and communal interests of the people.

The water resources are classified as being of high (1), medium (2) or low (3) importance to ecology (E), livelihood (L) and commercial development (C). According to this strategy, the Upper Mara was categorized E1L2C3, indicating the area is of high importance for ecological concerns related to water resources management, medium importance for livelihoods acknowledging the importance of small-scale subsistence farming, and relatively low importance for commercial development. The Lower Mara was ranked E1L2C2, indicating a high importance for ecological purposes, and medium importance for livelihood activities, with a majority of the population still dependent of water resources for subsistence farming; however, commercial activity is also of medium importance, acknowledging the importance of tourism and larger scale farming enterprises.

While the above is a first step towards the development of RQOs that could be used as targets for water resources management in the basin, they still require dissection in order to be more specific. RQOs that are most useful are either narrative or quantifiable measures that can be used to set targets for various aspects of the water resource. For example, in the above example, the lower Mara site was ranked E1L2C2 – taking the L2 (Livelihood medium importance), just how much water and of what quality is required to satisfy livelihood needs which are of medium importance?

Summary of implementation initiatives described at a workshop to discuss EF in Tanzania (IUCN, 2010)

Mr. Patrick Oloo representing the Ministry of Water and Irrigation noted that being a trans-boundary resource, Lake Victoria Basin Commission (LVBC) has initiated a project on the Mara River to build on work done by WWF – which included an eflow assessment. He mentioned that Mara is part of the Nile Basin and that there has been a programme running under the Nile Basin Initiative. This is the only basin in Kenya where an eflow assessment has been undertaken. He noted that in Kenya, policy formulation and implementation have been separated – while the Ministry of Water and Irrigation is in-charge of the former, Water Resources Management Authority (WRMA) is in charge of the latter. From the policy perspective, he noted that there are issues that need to be addressed to enhance the understanding on eflow and its importance to the river ecosystem, such as: carrying out continuous monitoring; cap on allocations; capacity building; developing a water allocation plan; and developing water catchment strategies. WRMA lack capacity to implement the eflow assessment because it is a new science that requires specific skills and knowledge sets.

The concern in Kenya was that the activities in the upper Mara were affecting the national parks (Masai Mara in Kenya and Serengeti in Tanzania) and that the country did not want to compromise its relationship with its neighbour (Tanzania). He noted that the Kenya government is undertaking the rehabilitation and management of Mau which is part of the Mara.

Section H: Monitoring issues.

The several reports which have been included in this review, almost without exception, present a recommendation to undertake monitoring of some aspect of the water resource system. There would be little point in reviewing all of these recommendations as without some mandate and without being on a path to implementation, they are nothing more than recommendations. What is more important is what monitoring is actually taking place?

The kind of monitoring that would be directly useful for the implementation of environmental flows is illustrated below (LVBC, 2010). (note this list is not exhaustive and would need to be tailored for the particular site and situation):

1. Functioning of natural sediment generation processes

    a. Presence of stable river banks

    b. Intact riparian zones

    c. Absence of large-scale erosion denuding landscapes

    d. Absence of excessive fine-scale sediment deposition in river channel

2. Occurrence of a variety of instream and riparian habitats to provide habitat for diverse species

    a. Adequate distribution of pools, runs and riffles

    b. Presence of lateral and channel bars

    c. Vegetated riparian zones that receive periodic inundation

3. Presence of sensitive species that reflect suitable water quality levels

    a. Rare or threatened fish species that depend on appropriate timing of variable flows for feeding and reproduction

    b. Sensitive invertebrate species that indicate subtle fluctuations in water quality and pollution levels

    c. Important riparian plant species that depend on seasonal inundation for germination

4. Adequate provision of human needs by water resources

    a. Year-round accessibility of water for domestic purposes

    b. High water quality to reduce the occurrence of disease

    c. Maintenance of tourism-dependent processes, such as water for wildlife habitats

Alternately the monitoring programme could be divided, having two main objectives:

1. Monitoring in order to update data and information in order to better understand the requirement for environmental flows at each site and in the basin as a whole.

2. Monitoring in order to test achievement of the desired river state or Ecological Management Category

Each of the above would need to be dissected into the variables of concern that require monitoring.

Some key documents which contain useful and possibly strategic guidelines for undertaking monitoring include:

The LVBC (2009) Biodiversity Strategy and Action Plan for Sustainable Management of the Mara River Basin, noted that implementation of the BSAP for the MRB will require regular monitoring and evaluation of the progress of the different planned activities, which will be based on pre-determined performance indicators. This BSAP has been written to elucidate a general strategy and approach to conserve critical biodiversity habitats throughout the MRB. Detailed work plans will need to be developed by the responsible actors for each priority activity, and these work plans will include a list of measurable performance indicators in terms of quantity, quality and timeframe. The implementing actors will be responsible for conducting on-the-ground monitoring, evaluation and reporting of activities and indicators to LVBC, as the overall coordinating body.

The LVBC (2010) Assessing Reserve Flows for the Mara River, noted that it is necessary to implement a comprehensive monitoring system on the Mara River to enable daily monitoring of the flow levels at multiple points in the basin, and to improve monitoring of permitted and non-permitted abstractions to reduce illegal abstractions and to develop an estimate of current abstraction levels.

The Environmental Flow Assessment Proceedings of the Final EFA Workshop (WWF-EARPO, 2007) said that more research into the relationship between water quality and flow levels would be helpful. Higher resolution temporal monitoring data is needed. A minimum frequency for water quality monitoring should be monthly for basic parameters, i.e. temperature, pH, dissolved oxygen, electrical conductivity, nutrients, biochemical oxygen demand, and more specialized analyses (e.g. pesticides and metals). There is a high priority to investigate water quality at very low flows. A new report is due to be published in the near future looking at the relationship between flow level and water quality and refining EF recommendations at critical low flows. The data collection was complete in June, 2010, and the findings will be published in a Follow-up EFA Report in early 2011.

In the report NBI, (2008a) Consulting Services for the Assessment and Design of Hydrometric Network and Guidance of Water Quality Survey for the Mara River, there is detail on how a hydrometric and water quality monitoring programme should be structured, but this in relation to general IWRM and not specifically for environmental flows.

The Water Quality Baseline Assessment Report: Mara River Basin, Kenya- Tanzania (GLOWS, 2007) noted that currently, there is little systematic monitoring of water quality in Mara River Basin. On the Kenyan side of the basin, the Ministry of Water and Irrigation has established water quality laboratories in the Narok and Bomet District Offices and a limited number of monitoring campaigns have been conducted. On the Tanzanian side of the basin the Ministry of Water has established a water quality laboratory in Musoma with support from the Lake Victoria Environmental Management Programme, and this office conducts occasional water quality campaigns into the lower Mara Basin. TANAPA conducts monthly water quality monitoring in Serengeti National Park (including at a UNESCO Ecohydrology study site), and Barrick Gold Mines has conducted regular monitoring of rivers in the area of its activities. Barrick's monitoring, however, is for the company's own compliance purposes and results are not routinely distributed to local authorities.

Section I: Successes, limitations and gaps

Management issues

1. Due to the transboundary nature of the Mara, the chief obstacle will be to overcome the National interests of the riparian countries and to harmonise these to suite the environment and thus the flow of benefits to society.

2. There is considerable data and information in the academic literature that would be of use to the management of EF in the Mara. This literature needs to be brought into the management realm. In the future, where possible, coordination of such academic exercises would be of benefit to the Mara.

3. Many development agencies, academic institutions and national and regional government initiatives have been involved in work on the Mara catchment. Every bit of the work that has been done adds value, but there are obvious challenges to make these efforts most effective. This requires considerable coordination which may not always have been effective but there are indications that there are efforts to improve this. A new initiative is to have a quarterly meeting of the coordinators of the different programmes (Subalusky, *pers com*), which will go a long way to sycnronising the situation.

Environmental flow (ecological) issues

4. The ecological consequences of NOT providing EF flows have only been superficially documented.

5. In the EF projects done on the Mara, there is only one site in Tanzania at the upper end of the river. This leaves unattended a significant reach of river in Tanzania and also the downstream Mara swamps before it joins Lake Victoria. It would be necessary to increase survey sites to both of these river reaches and to the swamps, in order to properly understand the Mara environmental flow requirements. Apparently there are plans to undertake this in 2010-11 by FIU under the TWB-MRB program (Subalusky, *pers com*).

6. The PES for all sites on the Mara were determined to be a B category – thus only slightly modified. This conflicts somewhat with the overall hype about the state of the river and needs further explanation as it is often stated that the river is in poor condition. Apparently flows in the river do not cease except during exceptional droughts, which implies that there is sufficient water remaining in the system to sustain the B category. The cause of this uncertainty may be that the present findings were based on a single site visit to determine the EF. A second survey has been carried out but these results are not yet integrated. These new results may throw light on this but there will be uncertainties developed if the new findings contradict the first in any significant way.

7. There is no detailed information presented on the quality of the hydrological data used for the EF, although there are statements that the hydrological information is poor on both Kenyan and Tanzanian sides.

8. The importance and sensitivity of the Mara River is generally related directly to the maintenance of goods and services for society. Unfortunately there are many other services provided by the river which are possibly even more important than those discussed above, but because they are not as obvious, may not gain the same level of support. For this reason, it is wise if the importance of the ecosystem in its own right is established, even if the provision of environmental services is not so obvious. Thus, in the management of a river, the importance of the ecosystem, as an ecosystem, needs to be established. There has been insufficient consideration of the importance of the Mara River ecosystem in this way, considering the species that it contains, the rare and endangered species, the ecological process that underlie the workings of the ecosystem, the role in maintaining channel form, in cleaning up polluted water and processing organic contaminants, the importance of the in-channel and riparian habitats etc etc. Are these ecosystems important on a local, regional and international scale – understanding of which would lend context to efforts to maintain them?

9. Future planning by water managers requires both greater understanding of the flow regime necessary to protect aquatic ecosystems as well as clear justification for how people benefit from the goods and services provided by these ecosystems.

10. There is also a need to understand the spatial and temporal variability in the Mara River flow regime as a function of climate and land characteristics. Also the spatial and temporal dynamics of flooding in the Mara Wetland as a function of Mara River discharge, water levels in Lake Victoria, and wetland geomorphology – something that will be addressed by MaraFlows. Then, there is a need to understand the spatial and temporal variability of water quality as a function of measured flow and flow indices along the river channel network and wetland, work that is also due to be published in 2011.

11. There is a real need to further study the fish, invertebrates and riparian vegetation of the Mara, which are so essential to establishment of the EF. Given the importance of mega-fuana in the basin, there would also be value in understanding the water requirements of these fauna (hippos, wildebeest, crocodiles etc).

Scenario issues

12. There is a prevailing sentiment that the ecosystem need only be conserved if it provides for people. While this view is true at a level and does at least acknowledge the relationship between the ecosystem and the value to society, leaving the judgment of this to stakeholders is fraught with dangers, as stakeholders do not always appreciate the provision of services from the ecosystem, mainly because they do not understand what is being provided to them. For example, can rural stakeholders understand the value to them of a carbon sink offered by a peat swamp? Do they understand the value of benthic invertebrates in purification of water of organic pollutants? Stakeholder often have a biased and short term view on the provision of these services, and thus cannot be relied on to be arbiters of what needs protection. It is thus strongly recommended, that a proper evaluation of the importance and sensitivity of the Mara River ecosystem is carried out.

13. There is reference to a "default standard for determining the Reserve in Kenya" (this does not appear to have been stated for Tanzania) which is the flow level that is exceeded 95% of the time, or Q_{95} (LVBC, 2010). It is recommended that the reserve should rather be estimated as outlined in the BBM approach even if at a low confidence level, which would be better than making use of such a "default standard".

14. The reserve process has defined Ecological Management Categories (EMC) – which become objectives for management. The determination of these categories was done on a purely ecological basis, and represents a category which the ecologists on the team feel would sustain the river ecosystem

and would not be an unreasonable objective to implement. Unfortunately what this EMC does not do, is take into consideration all of the other demands on the system, which may make this EMC unreasonable. A process to determine the needs of all stakeholders and the wider basin requirements, needs to be included in this process.

15. There are a number of initiatives that portray possible futures for the Mara and include information on obstacles and possible paths to improving the situation in the basin. There is however, no documented strategy which seeks to describe possible future scenarios for the basin in a way which would allow government to make a choice on the direction that management should take. Apparently this is being addressed by the WWF who are undertaking an SEA process in the basin ((Subalusky, *pers com*).

16. A proper process to describe resource quality objectives (RQOs) needs to be developed. Note that these may not be the same objectives for monitoring that emerged from the Reserve process, as they need to consider more than just the ecosystem e.g. they need to include users of the resource.

Chapter 6. A Critical Analysis

Following this review of all of the documents that were available that describe the management of environmental flows in Tanzania, the overall impression is one of an excellent job having been done! Clearly driven by an understanding that the declining flows in some rivers were starting to have a significantly negative impact on the environment and thus society, the country as a whole has taken brave and positive steps to solve the problem. Linking with a willing international community, who have shared funding and expertise, the country has legislated the requirements to protect environmental flows and has promoted the determination and implementation of environmental flows in four river basins. Tanzania has to be commended on its approach and on its willingness to move into relatively uncharted waters, where science is still struggling to provide the tools needed to manage this issue of environmental flows.

Looking back over time at all the EF projects that have been carried out in Tanzania, it could be argued that greater synchronisation of the approaches and efforts country-wide would have made for greater efficiency and could have resulted in a more harmonious programme for management of environmental flows in Tanzania. As it stands, the programmes based in each catchment are substantially dissimilar which presents a number of challenges to the resources of Tanzania. While it is easy to say this with hind-sight, going forward as a country it would seem that there are three possibilities:

1. Each of the basins continues with its independent approach, but synchronisation at a National level is promoted to share the lessons learned and also to share the expertise that has been developed.

2. Acknowledge the commonalities and differences between the approach of each basin and fill in the gaps to ensure that each basin delivers a minimal set of information. The Sections that have been used in this review (see below) provide a possible minimum list of information that needs to be developed if environmental flows are to be implemented in all basins.

3. As a country, make a decision on a single approach and move to adopt this for all basins. Where this approach is different to what has already been done in a basin, it would be possible to make use of existing data and information to populate a new approach, perhaps with the addition of critical missing information.

Considering the above in the light of what has been covered in this review, and given the great investment that has already taken place in the different basins, and acknowledging that the enthusiasm of each of these teams needs to remain intact, perhaps the second of the above possibilities would be a most appropriate way forward? It would be useful for this to be considered at a National level.

Following the review of several methods and their application, the question is asked what constitutes the ideal "method" or "approach" for the management of environmental flows? Overall this can be broken into two main aspects:

1. The determination of the flow requirements required to maintain an ecosystem in a particular class or condition.

2. The integration of the above into wider catchment management processes including the management of the water resource to satisfy the needs of society.

In order to cover the entire range of issues that could be regarded as the determination AND management of environmental flows, this review has broken each case study into different sections that it could be argued, constitute the complete EF procedure, i.e.:

Section A – Initiation and scope of study.

Section B - Process to define areas of study and assessment.

Section C - Evaluation of the original and present state of the systems.

Section D - Evaluating the importance and sensitivity of the systems.

Section E - Quantifying the environmental flow requirements.

Section F - Setting a vision for the river and development of scenarios.

Section G - Implementation of environmental flows.

Section H – Monitoring (and review).

It is recommended that in the future, all studies should be designed to ensure that all of these components are addressed. As can be seen in this review, each of the different methods used (DRIFT, BBM etc) can be made to fit into these Sections although in some cases there will be gaps in the information that need to be filled.

These sections have been used below to analyse the work that has been done in Tanzania.

Section A – Initiation and scope of studies.

The policy situation for the management of environmental flows in Tanzania is excellent, as is the structure for dissemination of authority to agencies on the ground. These government agencies have followed a long path of working with the support of international support agencies, and in this way have described the environmental flows, to a greater or lesser degree, in all four catchments that have been reviewed here.

There have been concerns expressed (March 2010 workshop) that compliance with existing laws is poor which mitigates against successful implementation of environmental flows. This is a political issue that can only be solved at that level.

Section B - Process to define areas of study and assessment.

In few of the studies has there been a detailed presentation of how the areas to be studied, and the sites chosen to represent the area, were decided on. Normally this should be based on a combination of ecological factors and other practical and catchment features. In the classical EF approach, there should be detailed documentation of the suitability of each site as a site for assessment.

In some of the studies, the number and location of sites was less than ideal for a full understanding of the environmental flow requirements of the river. This includes the integration of the estuary into the river environmental flow assessment, as unless these two are aligned then one of these systems may be disadvantaged.

Section C - Evaluation of the original and present state of the systems.

In all of the studies there has been some evaluation of the original and present state of the system, but in some this is limited to stream flow and knowledge of the rest of the ecosystem is poor. Ideally the documentation of the original state should be for a wide range of ecosystem components (quantity, quality, habitat and biota), each of which will tell something different about the state of the ecosystem.

For a full EF assessment, it is imperative that there is some knowledge of the natural reference condition of the ecosystem, which is necessary in order to be able to measure the extent of degradation that has taken place. It is then necessary to quantify the present state in a way that enables measurable objectives (for the quantity, quality, habitat and biota) to be set for future management activities. In some of the case studies reviewed here, this has been well done, but in others there remains a great deal to document.

Unfortunately, where changes to a system are already substantial, then the opportunity to gain an understanding of the natural reference condition may be lost BUT this can be partially rectified through a process of considering unimpacted but neighbouring systems within the same ecoregion. In such situations it is prudent to develop a Reference Condition for a river system, even where this is hypothetical (but based on the best available data and information). This highlights the need to gather baseline data and information on the river systems before it is too late!

Hydrological records in most catchments were inhibiting to the process. Increased monitoring in the future is strongly recommended. In the same way, the level of knowledge of the components of the ecosystem (biological and physical), is in many of the studies rather poor. Over time, this should be supplemented by implementation of an ongoing and carefully designed monitoring programme, which will allow the EF assessments to be improved upon when they come up for review.

Section D - Evaluating the importance and sensitivity of the systems.

Most of the studies reviewed express strong sentiments about the importance of the river to the country, to its people etc. While this forms a part of the assessment that is necessary, what is generally missing is an evaluation of the importance of the rivers in terms that are less obvious. This may include aspects of the ecosystem that are completely beyond the understanding of stakeholders and political leaders but somehow they need to be included in management objectives in a way that makes them acceptable. For example, the contribution of benthic macroinvertebrate diversity to the purification of pollutants in the river water; the necessity of maintaining a stream morphology and preventing the sedimentation of deep pools; the contribution of wetlands as sinks of carbon etc etc. All of these issues need to be protected for the long term benefit of society, although society may not be able to understand how this works. The need here is for scientists to present these more subtle issues in ways that are acceptable to managers and stakeholders so that they may be included in management strategies.

An issue that requires a thorough understanding of the ecosystem but has been given little attention, is the sensitivity of the ecosystems to stressors. Ultimately this forms the basis of the environmental flow assessment, but a real understanding of these relationships is generally limited and can only be built up by sustained investigation over a long time.

Section E - Quantifying the environmental flow requirements.

At the centre of any environmental flows assessment, is a system or model that assists with the translation of large amounts of biophysical data in order to assist with the process of deciding on the flow requirement of each component (quality, habitat and biota) of the ecosystem. The literature contains several reviews of these approaches which have multiplied following the creative nature of scientists and the need to produce a model which is most appropriate. It could be said that this proliferation of methods is an indication that no single method has yet been developed which has been accepted by both scientists and resource managers.

A range of methods have been applied in Tanzania i.e. DRIFT, BBM, Desktop Model and a combination based on the Savannah approach. Each of these approaches is significantly different from the other, each having advantages and disadvantages. Methods such as DRIFT are relatively complex, while other approaches e.g. the Desktop Model, are probably deficient for the task. For Tanzania, the use of such a diverse array of methods may be counter-productive and there is possibly a need for a decision on the most appropriate way forward. In those basins where there has already been considerable investment in a particular approach, the way forward has been discussed under Section A above. For basins where no approach has yet been used, consideration needs to be given as to what would be the most appropriate model to use. Unfortunately the comparison of models is not straight forward as they do different things and have different outputs. The BBM method has been criticised as it does not integrate easily with possible scenarios for water flow that may be used by water resource planners, something which was introduced by the DRIFT model (and others which are available). Unfortunately, this introduces a high level of complexity into the presentation of environmental flows and moves the approach into the preserve of only a few. The BBM on the other hand, is immediately understandable by scientists and managers alike, and if accepted into a framework for planning which is based on the principles of adaptive management, may be the more appropriate system for Tanzania. It must be noted though, that this is the view of this review, and will no doubt be contested by some!

The science of understanding the relationship between environmental flows and the health of the ecosystem, in particular different components of the ecosystem such as fish, invertebrates and riparian vegetation, is in its infancy. In Tanzania this is no different. Further understanding elicited by research would greatly enable the process of environmental flow assessment and help to secure sustainable use of the water resource. While international research efforts will be providing some of this understanding, the unique aspects of the Tanzanian ecosystems will require Tanzanian research.

Section F - Setting a vision for the river and development of scenarios.

The first step for any resource management strategy should be the setting of a Vision for the resource. The vision describes society's aspirations for a particular resource. The description is often a narrative one but it encapsulates a high level objective that provides a framework for management to work in. To some extent this is done by statements in the legislation, but this needs to be downscaled to the basin level. That produced by the Wami/Ruvu Basin Water Office is a good example although it could be given more detail in relation to environmental flows.

In consideration of the benefits of the river systems to society under various resource use scenarios, there is an overriding consideration of the provisioning services provided by these river basins e.g. resources for direct consumption. There is a danger that other types of services, which may be more important e.g. supporting, cultural and regulating services, are not being given fair consideration. Unless these are given equal priority, poor decisions about the management of the resource may result.

Development of scenarios for the cases has been extremely variable. The Pangani (DRIFT) approach provided a very detailed consideration of the options for water use. The Ruaha reports document a very pragmatic approach to problems being faced by the basin. Other cases are less structured in their consideration of this. It is recommended that a more classical scenario assessment be undertaken in each river basin, where high level options are made available for decision makers.

Consultation with stakeholders in the development of scenarios should not be overlooked. Unless there is buy-in from stakeholders, implementation becomes difficult. Government should also take the stance that "a problem shared is a problem halved". Inclusion of stakeholders reduces the risk of failure by government.

Section G - Implementation of environmental flows.

To date some excellent work has been carried out on the assessment of environmental flows and it is clear that this situation now moving into the realm of implementation. Some of the cases are actively making decisions on resource management based on these environmental flows which is a most positive step. The consequences of *not* providing environmental flows, both to the ecosystem and to society, needs to be made clear. This aspect will in the future require active work, to continually reinforce the need to maintain environmental flows particularly in situations where there is a contest for resources. It is the experience in some other countries, that when the enthusiasm of installing environmental flows has passed, pressing issues of water provision etc often smother out the reasoned process of protecting the resource that was followed before. This needs to be guarded against.

Tom Le Quesne (March 2010 workshop) noted several issues about implementation that are of relevance globally but also in Tanzania. These may be summarised as follows:

1. Implementation is the big challenge and there needs to be a guard against overcomplicating things.

2. Implementation needs to be phased.

   a. Progressive implementation. There are no countries which have the capacity to implement fully – so need to do what is possible.

   b. Catchments for implementation – limit the number of catchments for implementation and introduce in general terms first and then advance over time.

1. Introduce a cap on the total amount of water that can be abstracted as soon as possible, as once a river has been over-allocated, it is difficult to reverse the situation. Thus introduce a cap even if not strongly defensible as this can always be improved. If there are objections, then move to a more detailed study etc. A warning is found in Australia where the government is going to spend 5 billion dollars to buy back water rights.

2. Be opportunistic in instituting environmental flows e.g. droughts can open debate and assist with initiating EF. Often this does not happen in a carefully planned way.

3. There is a need to allow some flexibility in the approaches and methodologies that are used. It is a mistake to set too much in stone with one method – rather adapt as necessary. But – do set fixed time tables – and not allow these to be flexible.

5. Clarity of intuitional frameworks is important as is independent oversight. Responsibility must be clear. The advantages in Kenya and Tanzania are that new acts do set out responsibilities quite clearly. Independent scrutiny is also important – the dilemma is whether the body responsible for EF is the same as that for implementation. There are benefits to both situations.

6. Build support and capacity through on-the-ground proof-of-concept projects. The projects taking place in Tanzania are good examples.

7. Do not exceed the ability to implement – most countries who try to implement, come up with an approach which is more complex than they can implement.

The science of Adaptive Management needs to be firmly embraced as Tanzania moves towards implementation. This acknowledges that any environmental flow assessment is just a first hypothesis, and will prove to be inaccurate in some respects and will need to be refined over time. It should never be considered that an EF is final and absolute. This has significant ramifications for the allocation of water resources and issuing of licenses for abstractors etc, as there needs to be acknowledgement that over time things will change. Failure to be adaptive will inevitably lead to a "locked in" situation where managers come under increasing pressure to force a situation to work even where it is obvious that it cannot. A good review of this aspect can be found in Allen (2007).

There has been little movement to establish Resource Quality Objectives for the rivers. What are RQOs? *The Resource Quality Objectives for a water resource are a numerical or descriptive statement of the conditions which should be met in the receiving water resource, in terms of resource quality, in order to ensure that the water resource is protected (DWAF, 1999).* The purpose and application of objectives is documented as follows (shortened in this case):

- They represent a goal for desired protection towards which management can be directed.

- They provide a clearly understood line between which activities and impacts are acceptable and not. This includes the impacts of point sources, non-point sources, land use and development, water abstraction etc.

- They are a baseline for measuring the success of management and for reviewing the effectiveness of source directed control and regulatory activities.

- They provide a stable framework for a time period, for both resource managers and the regulatory community to undertake decision making and planning.

The National Water Resources Strategy of South Africa (DWAF, 2004) sates that Resource Quality Objectives provide numerical and/or descriptive statements about the biological, chemical and physical attributes that characterise a resource for the level of protection defined by its class. Thus resource quality objectives might describe, among other things, the quantity, pattern and timing of instream flow; water quality; the character and condition of riparian habitat, and the characteristics and condition of the aquatic biota."

It also states that "resource quality objectives must take account of user requirements and the class of the resource. Accordingly, the determination of the management class of a resource and the related Reserve and resource quality objectives will usually be undertaken as an integrated exercise."

In some Tanzanian cases RQOs have been considered at a high level (e.g. the EMC should be a C category), but this has not been dissected into meaningful and objective standard which can be used for monitoring. This was well done for the Great Ruaha River which can act as a model for this approach. Unfortunately not considered are resource objectives in terms of user requirement, for example what water quality is required by the people drinking directly from the rivers? This water quality may be different from that required to protect the resource.

Section H - Monitoring issues.

The final phase of all of the development and application of environmental flow assessments should be to install a monitoring programme. This is important for a number of reasons. First, to monitor compliance of implementation against resource quality objectives. Second, to increase the base of knowledge so that the environmental flow assessments can be refined over time. Third, there is an axiom that says that "you cannot manage what you do not measure". Unless there is an ongoing understanding of where the resource is at any time, management becomes *ad hoc* and inefficient and decisions on resource use become driven by the wrong factors. There is little indication yet that monitoring will be instituted in all of the Tanzanian basins. This is an important objective.

Chapter 7. A way forward - Outcomes from a Tanzanian Workshop

(Extract of a report by Katharine Cross of the IUCN (2010) entitled "Report on a Workshop on Environmental Flows Review - The Future of Environmental Flows: Providing Water for Nature and People held in Morogoro between August 2nd and 4th 2010).

In order to take the findings of the above review towards effective management of environmental flows in Tanzania, the IUCN organized a workshop to present a draft of the above review, validate the information and develop the way forward for operationalizing and implementing EF in Tanzania and Kenya. The workshop was held between August 2nd and 4th, 2010 in Morogoro, Tanzania and convened by Pangani River Basin Management Project[1] and IUCN. The workshop was attended by over 40 (forty) participants drawn from the a number of Basin Water Boards in Tanzania, Ministry of Water and Irrigation (Tanzania and Kenya), Vice President's Office (Division of Environment), Integrated Water, Sanitation and Hygiene (iWASH), University of Dar Es Salaam, Sokoine University, members of the Tanzanian EFlow Assessment Team, experts on eflow from South Africa (Southern Waters and Institute of Natural Resources) UNDP Tanzania Office, SNV Netherlands Development Organization, WWF, UNEP and IUCN. The workshop was facilitated by Prof. Francis Mutua from the University of Nairobi, Department of Meteorology/School of Physical Science, Chiromo Campus.

Workshop objectives:

1. To share experience and knowledge on EF assessments in Tanzania and Kenya;
2. To determine possible criteria for harmonized EF assessment in Tanzania; and
3. To discuss and determine how to operationalize EF assessments to achieve wise and sustainable management of river flows

Key characteristics of a good eflow assessment

In a group work setting, the participants discussed the key characteristics of a good eflows assessment from a technical and socio-economic viewpoints. The main outputs of this discussion can be summarized as follows:

- Policies: There is a need for viable institutions which are economically sustainable, and there must be an enabling environment for these institutions to function which includes national policies and legislation supporting all levels of water management that provides for the environment as well as human well-being.
- Teamwork: A multi-disciplinary team (i.e. hydrology, economics, vegetation) is necessary for an eflow assessment, and there should be sufficient capacity building so that local teams can sustain the current and future eflows initiatives.

[1] The Pangani River Basin Management Project is generating technical information and developing participatory forums to strengthen Integrated Water Resources Management in the Pangani Basin, including mainstreaming climate change, to support the equitable provision and wise governance of freshwater for livelihoods and environment for current and future generations. The Pangani Basin Water Board is implementing the project with technical assistance from IUCN (International Union for Conservation of Nature), the Netherlands Development Organization (SNV) and the local NGO PAMOJA. The project is financially supported by the IUCN Water & Nature Initiative, the Government of Tanzania, the European Commission through a grant from the EU-ACP Water Facility, and the Global Environment Facility through UNDP.

- Consultations: There should be sufficient funds in eflows assessments for comprehensive stakeholder involvement that incorporates gender considerations and demographic dynamics (i.e. women and youth need to be included and consulted)

- General considerations about methods: A number of different issues need to be incorporated such as development activities and infrastructure that influence flows; water use; climate change; upstream-downstream relationships; available data; and inclusion of indigenous knowledge;

- Specific consideration of methods: Different types of studies should be undertaken including hydraulics, hydrology, vegetation , invertebrates, basin delineation, water quality, sediments, socio-economics and macro-economics, etc

- Inputs: This reflected on the type of information gathered to be input into an eflow decision support tool. For example, this includes information on ecosystem services, land use changes, socio-economic dynamics, water quality, and biological indicators of river health.

- Outputs: The outputs from an eflows assessment must be of good scientific quality, there should be an implementation plan along with a strategy to communicate and disseminate results;

Operationalisation of eflows

Participants in a group setting discussed the requirements and enabling conditions needed to operationalize eflows. In summary, the discussions touched on the following: policy and legislation; assessment and modeling; allocation and licensing procedures; reallocation mechanisms; monitoring and enforcement; and organizational requirements. Through this visioning exercise, the groups came up with a number of targets that would enable eflows to be operationalized.

The main targets for implementation included:

- Regulations and guidelines for eflows are in place to implement the act

- Eflows have been determined, and

- Skills, equipment and finances to carry out eflow assessments are developed and operational.

The main targets for operationalization were:

- The desired configuration of River Health state is determined

- Water licenses have been re-evaluated to support the desired configuration, and

- Monitoring of the state of environmental resources including Eflows is enforced.

Action plans for implementation

On the basis of the above targets, the participants in 3 groups developed broad action plans as per the above categorized targets. The action plan had the following components:

- Barriers,

- Opportunities,

- What needs to be done to overcome the barrier and use the opportunities available,

- What resources are required to do this,
- Who needs to do this (responsibilities),
- When should it be done (time line) and
- What will indicate that the target has been achieved (milestone).

From these broad action plans, the basins are expected to use this framework to develop basin-specific detailed action plans. Basins were encouraged to share the workshop outputs and action plans with the Ministry of Water and Irrigation as well as other basins as a first step in implementation and operationalization of eflows.

Experience of undertaking eflow assessments from the four basins

Basin Water Officers from Pangani, Wami-Ruvu and and Rufiji, as well as the representative from the Ministry of Water and Irrigation in Kenya took part in a panel discussion to reflect on the challenges and experiences from undertaking flow assessments. The panel discussion was moderated by Dr. Jackie King and Dr. Cate Brown (both experts on eflow, from South Africa). Summaries of these presentations for each basin have been included under the heading of ***Implementation*** in each of the chapters above.

Chapter 8. Bibliography

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The Pangani River Basin Management Project

The Pangani River Basin Management Project is generating technical information and developing participatory forums to strengthen Integrated Water Resources Management in the Pangani Basin, including mainstreaming climate change, to support the equitable provision and wise governance of freshwater for livelihoods and environment for current and future generations.

The Pangani Basin Water Board is implementing the project with technical assistance from IUCN (International Union for Conservation of Nature), the Netherlands Development Organization (SNV) and the local NGO PAMOJA. The project is financially supported by the IUCN Water & Nature Initiative, the Government of Tanzania, the European Commission through a grant from the EU-ACP Water Facility, and the Global Environment Facility through UNDP.