Upstream/downstream competition for water in the Usangu Basin, Tanzania

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1. Introduction

This paper describes some of the interim findings of the hydrology and water resources programme of the SMUWC project, which started in September 1998. This project, the Sustainable Management of the Usangu Wetland and its Catchment, was established at the request of the Government of Tanzania to develop an integrated approach to natural resource management in Usangu, including water, land, livestock, wildlife and fisheries. The project is funded by the UK Department for International Development, and is being undertaken by a consortium lead by HTS Consultants Ltd.

Water is under pressure from competing uses, causing changes in the hydrology of the basin and in the availability of the resource to others within the basin and downstream. This has resulted not only in social conflict between upstream users but also demands from downstream users, who wield considerable economic and political power, for upstream use of water to be restricted.

Initial work has focused on gaining an understanding of the underlying hydrology, and the causes of the water problems in Usangu, which will form the basis for a strategy for improved management of water.

2. The Usangu basin

The catchment draining to the Usangu wetland lies in the south west of Tanzania between the towns of Mbeya and Iringa. The catchment forms the headwaters of the Great Ruaha River, which is a major tributary of the Rufiji River. The area covers 20 800 km^2, of which 23% is alluvial plains at an elevation of 1 000 to 1 100 masl, and the remaining 77% forms the high catchment, ranging in altitude from 1 100 to just under 3 000 masl.

The high catchment receives 900-1 500 mm of rainfall annually while the plains receive 650-800 mm. Rainfall is highly seasonal, occurring mainly between December and April. A long dry season occurs between May and November.

The Usangu basin contains a number of distinct water resources subsystems (Figure 1). The relatively wet high catchment on the southern and western boundary of the project area forms the source area for a number of perennial and seasonal rivers which flow into the Usangu Plains.

The plains consist of alluvial fans, seasonally flooded open grassland and perennial swamp. The soils of the last two subareas are vertisols, which are deep cracking clay soils. The alluvial fans form an almost continuous band around the margins of the central plains. The rivers cross the alluvial fans to the central plains. Owing to the erodible nature of the fan sediments and the large flood flows that may occur, river courses are very unstable and many channel changes, both natural and man-made, have occurred. Where drainage is inhibited by the topography, relatively small swamps have developed, called ’fan swamps’, which may develop or disappear with changes in the courses of rivers.

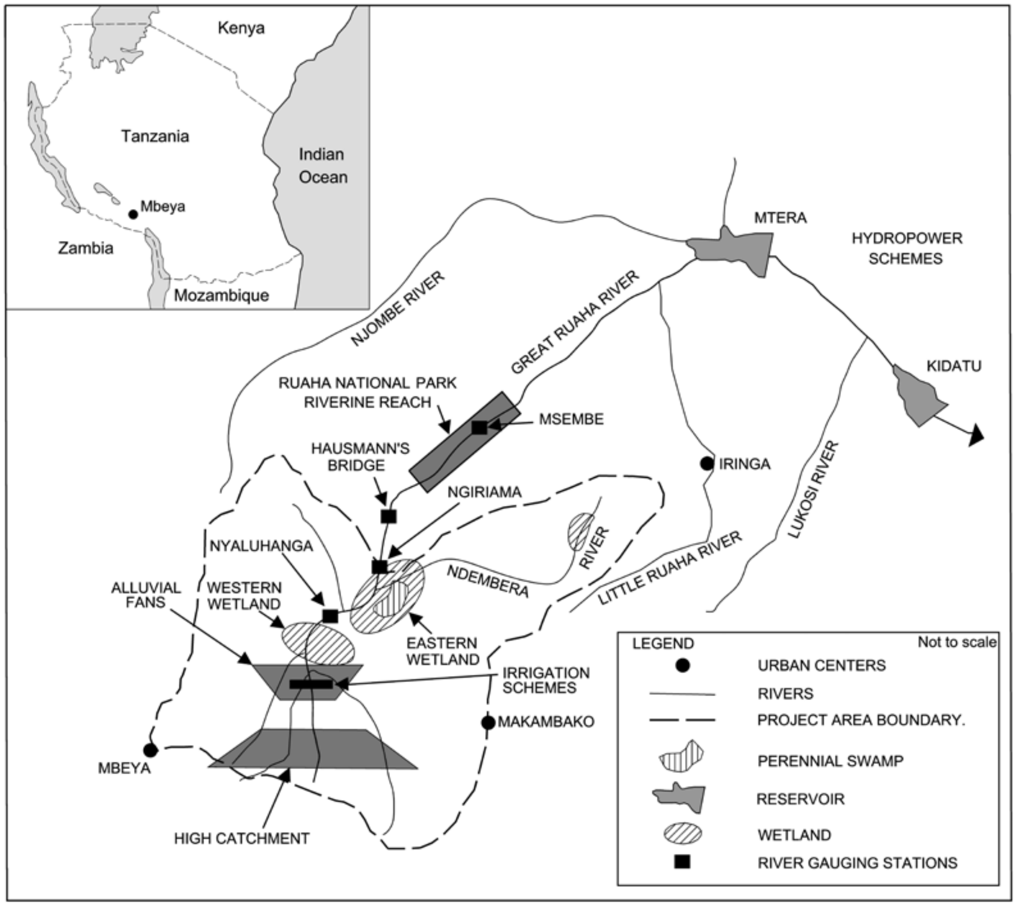

Figure 1 Major water resources subsystems

Irrigated agriculture is situated on the middle to lower parts of alluvial fans on the southern margin of the Usangu wetland. The irrigation schemes consist of large state-owned rice farms and separate small-holder areas. Irrigation supplements rainfall, and depends on water diverted from both perennial and seasonal rivers. Rainfed cultivation, some using water harvesting techniques, exists on the upper parts of the fans where rainfall is slightly higher.

Downstream the central plains are divided into the Western Wetland and Eastern Wetland by a constriction at Nyaluhanga. This constriction, essentially higher ground in the centre of the plains, may be due to a rise in the underlying basement rocks and the meeting of alluvial fans from the north and south. The Western Wetland consists of seasonally flooded wooded and grassland areas, not necessarily contiguous, surrounded by unflooded woodlands. The Eastern Wetland consists of seasonally flooded grassland and a perennial swamp containing swamp vegetation. The main inflow to the Eastern Wetland is the outflow from the Western Wetland.

Water exits the Eastern Wetland at N'Giriama over a natural rock sill which acts as a spillway. The outflow forms the Great Ruaha River which flows northeastwards through the Ruaha National Park. The river is an important source of water for wildlife in the park. Downstream of the park, the Great Ruaha River flows into the Mtera and Kidatu hydropower reservoirs.

3. Water resources demands

The water resources of Usangu are exploited both within the Usangu basin and downstream. Principal demands within the basin include:

- Wet and dry season irrigation
- Livestock watering
- Domestic supplies
- Environment (aquatic ecology) of the Usangu wetland.

Principal uses of the Great Ruaha River downstream of Usangu are:

- Environmental (maintenance of the aquatic ecology, wildlife watering and aesthetic conditions for tourists along the Great Ruaha River in the Ruaha National Park)
- Hydropower generation by Mtera and Kidatu reservoirs.

Irrigation using diverted river water is the greatest source of demand for water within Usangu. Paddy rice is irrigated in the wet season while maize and vegetables are irrigated in the dry season. The use of fertilisers and pesticides on the irrigated areas is currently at a very low level, so there are no significant water quality issues. Figure 2 shows the growth in the area of irrigated rice in the Usangu Plains. The area irrigated is dynamic and complex, varying from year to year depending on the availability of water in the rivers for diversion. It is estimated that the total irrigated area of wet season rice is 41 000 ha, while dry season irrigation covers 2 500 ha. The maximum irrigable area has been estimated as 55 000 ha (Hazelwood and Livingstone, 1978; SMUWC, 2000), so the graph in Figure 2 cannot continue to rise indefinitely with the same gradient as at present.

The two main demands downstream are for environmental requirements in the Ruaha National Park and hydropower generation at Mtera and Kidatu reservoirs. However, their exact needs for water differ. The National Park requires a continuous flow of water in the Great Ruaha River throughout the year, which provides a habitat for hippopotami, fish and other aquatic life, as well as aesthetic viewing conditions for tourists. In particular the flow at the end of the dry season should preferably not fall outside the range 0.5 to 3 $m^3 s^{-1}$, although it is known that occasionally, as in 1954, the river dried up naturally.

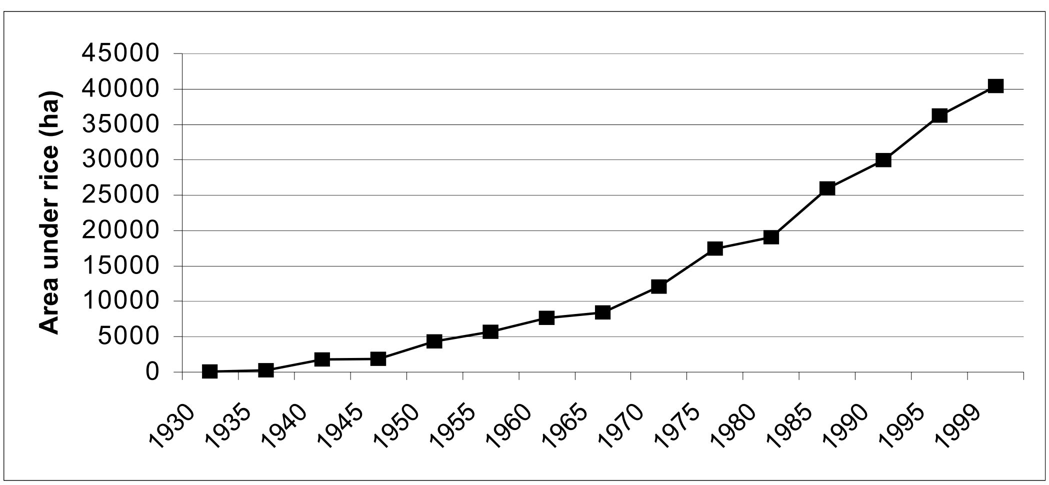

Figure 2 Growth of area under rice in Usangu Plains

The Mtera and Kidatu dams, which together generate 39% of all electricity in Tanzania, both require inflows and management of reservoir water levels and spill releases in order to provide an optimum supply of power. Storage in Mtera (volumetrically much the larger of the two) is controlled mainly by the volume and timing of the annual flood passing down all inflowing rivers. Storage is not greatly effected by dry season inflows which are very small in relation to the volume of the reservoir and evaporation rates from the reservoir surface.

The main water resource issue has arisen as a result of the ceasing of outflow from the Usangu wetland into the Great Ruaha River during the dry season each year since 1994. Although the river is known to dry up naturally, the ceasing of the flow each year may be without precedent in living memory. This has caused widespread mortality of fish and some hippopotami in the National Park, and created unaesthetic conditions in the remaining pools. It has also been held responsible for the decline in reservoir levels at Mtera since 1989. Blame for these reduced flows has been apportioned to climate change and excessive water use upstream.

To illustrate the drying up of the river flow in the dry season, Table 1 lists the dates on which the outflow from the Usangu wetland ceased and then resumed and the duration of the period of no flow in each case. There is a tendency for dates on which flow stops to become earlier each year and for the length of the periods with no flow to get longer. The river even dried up in the dry season of 1998, following a very wet season which had been associated with the 'el niño' phenomenon.

Table 1 Periods of no flow in Great Ruaha River in the Ruaha National Park

Year	*Date flow stopped*	*Date flow restarted*	*Period of no flow (days)*
1993	Did not stop		0
1994	17 November	15 December	28
1995	20 October	15 December	56
1996	17 October	16 January 1997	91
1997	25 September	25 November	61
1998	18 November	19 January 1999	62
1999	21 September	10 January 2000	111

Key questions facing the SMUWC project are therefore:

- What are the causes of this trend in reduced dry season flows?
- Can water resources in Usangu be managed so as to cause the outflow from the wetland into the Great Ruaha River to continue through most dry seasons?

In addition to these issues arising from competition between users downstream of Usangu and those living in Usangu, there are also issues over access to water within the Usangu basin itself. Diversion of water from rivers for irrigation by upstream farmers has led to shortages for downstream farmers. Competition for water also exists between 'top end' and 'tail end' farmers on the same irrigation furrow. This has resulted in disputes between villages along rivers and between farmers on furrows. Problems of access for livestock to water in the irrigation schemes also exist and this has sometimes resulted in conflict between irrigators and livestock keepers.

4. Hydrological analysis

4.1 Annual flows

Figure 3 shows the sequence of average annual flows in the Great Ruaha River at Msembe located in the Ruaha National Park. There appears to be a slight downward trend in annual flows in this river, but statistical analysis shows that the trend is not significant.

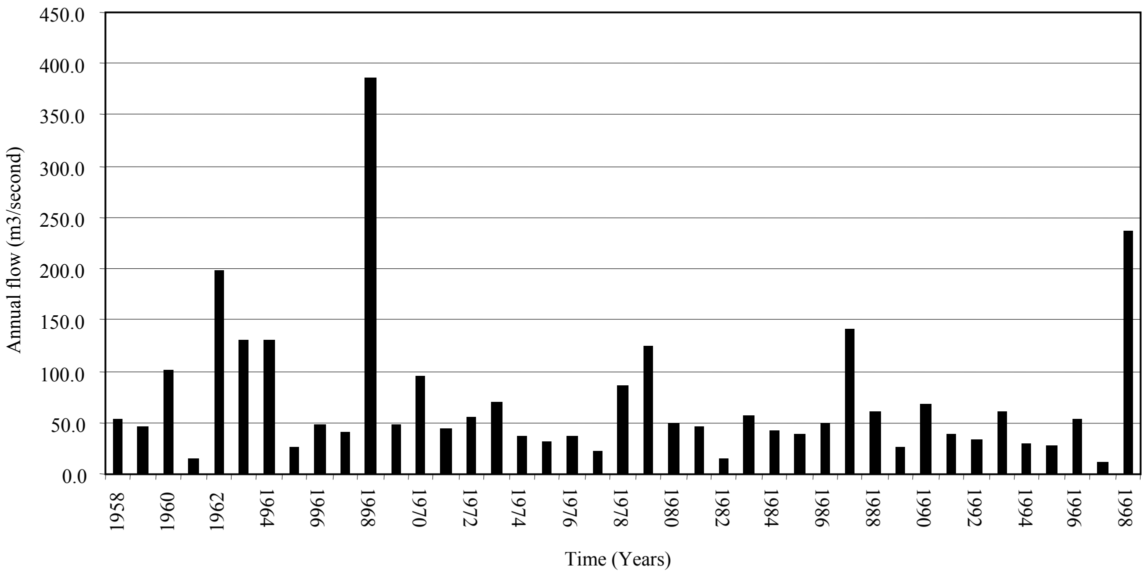

Figure 3 Average annual flows in the Great Ruaha River at Msembe

Storage in Mtera reservoir is controlled mainly by the volume of the annual flood passing down all inflowing rivers and the reservoir operating policy. The electricity generating authority's perception is that inflows to Mtera have been decreasing in recent years. But this figure shows that no such decrease has taken place.

4.2 Dry season flows

Figure 4 shows the average dry season flows (1 July-30 November) in the Great Ruaha River at Msembe. This figure shows that reduction in dry season flows in the Great Ruaha River is not a new phenomenon, but has been occurring since at least the mid 1970s. Only when it caused the Great Ruaha River to dry up in 1994 and in each subsequent year has public awareness been raised.

Since the volume of water contributed during the dry season is extremely small compared to that during the wet season, it is possible for the decline in dry season flows to occur while the volumes of annual flow, mentioned above, show no noticeable decrease.

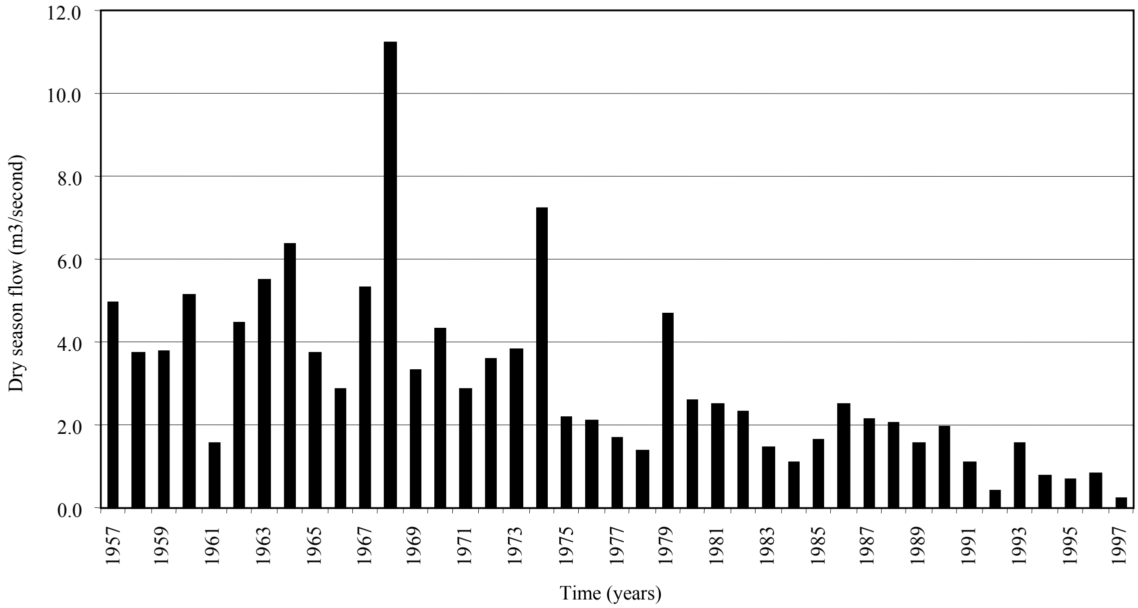

Figure 4 Average dry season flows (1 July-30 November) in the Great Ruaha River at Msembe

Another way of illustrating this point is by taking the daily flow record at Hausmann's Bridge gauging station, just downstream of Usangu, and using the rating curve at the swamp outlet at N'Giriama to convert these flows to the equivalent water levels in the wetland upstream of the outlet (Figure 5). While in the early part of the record the lowest water level at the end of the dry season lay about 1 metre above the level of the outflow sill, this difference was less in subsequent years, until recently it actually dipped below the sill level. But examination of the peak levels reached each year shows that there has been no corresponding decline in their values; in fact it appears that levels reached during the 1990s were, if anything, slightly higher than those reached during the mid-1970s.

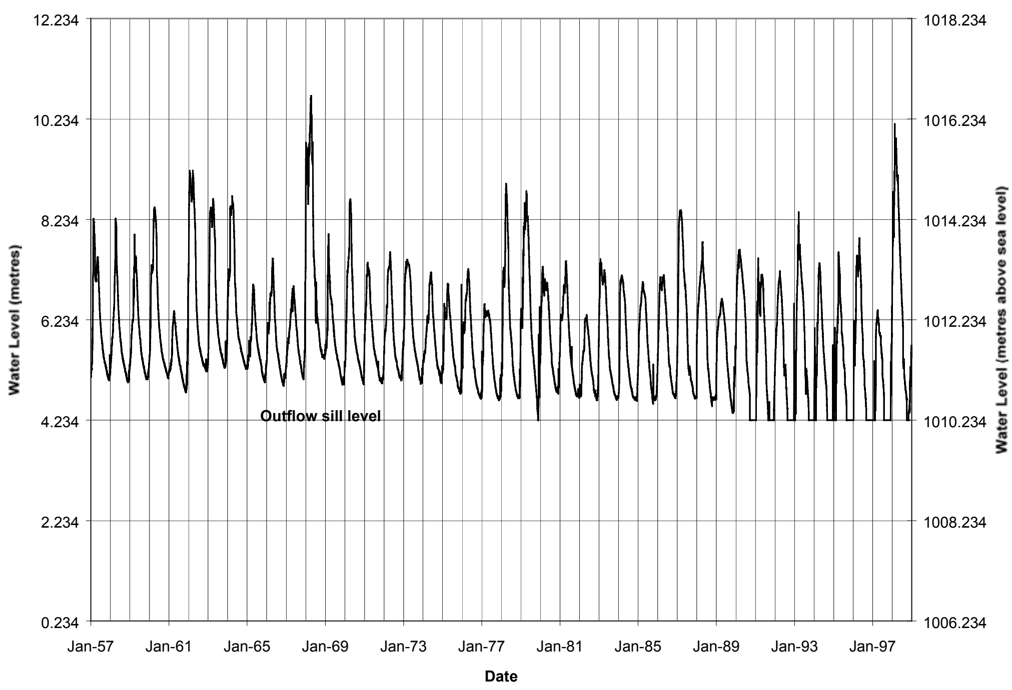

Figure 5 Equivalent water levels at N'Giriama from the reconstructed Hausmann's Bridge flow records

To find the reasons for this reduction in dry season flows, ten separate hypotheses were formulated. Many reasons have been offered by previous commentators (Moirana and Nahonyo, 1996; Kikula *et al*, 1996) and the ones that have been eliminated so far are:

- Decreasing trend in rainfall over the high catchment
- Increasing trend in evaporation over the plains
- Reduction in surface runoff from the plains
- Effects of cattle trampling in the seasonal wetland
- Domestic water consumption
- Livestock water consumption
- Deforestation in the high catchment
- Reduction in groundwater contribution to downstream flows.

For example, Table 2 indicates that the total water consumption by livestock is equivalent to that consumed by 109 hectares of irrigated rice. This latter area is very small compared to the present total area, 41 000 hectares, of irrigated rice in Usangu. It is concluded that livestock demand for drinking water cannot contribute significantly to the losses of water which are occurring in Usangu. Similarly domestic water consumption is equivalent to that of 83 hectares of rice.

Table 2 Livestock water demand

Stock type	***Unit demand (l/head/day)***	***Approximate population***	***Annual demand (million m^3)***	***Equivalent No hectares of rice***
Cattle	30	300,000	3.285	106
Sheep and goats	3	65,000	0.071	2
Donkeys	35	3,000	0.038	1
Total			**3.394**	**109**

The analyses of the hypotheses have identified a number of factors that could contribute to the drying up of the Great Ruaha River in the dry season. It is probably a combination of these that is the true cause. Essentially, the reduction in dry season outflows must be due to one or both of:

- A reduction in inflow to the Eastern wetland in the dry season and possibly also in the wet season
- Changes occurring in the Eastern Wetland itself.

That dry season inflows to the Eastern Wetland have reduced, contributing to the reduced outflow, is beyond question. Inflow from the Western Wetland through Nyaluhanga has been observed to cease in the dry seasons of 1998 and 1999. A number of factors can contribute to these reduced flows and the contribution or importance of each needs to be determined.

Most important is the abstraction of large proportions (averaging 87% across all catchments and up to 100% on individual catchments) of dry season river flows by both state farms and smallholder irrigation schemes. Using a net irrigation demand process model, it is estimated that only 28% of the dry season river flow is required for meeting crop water requirements on the 2 500 ha of non-rice crops that are actually irrigated during the dry season (Table 3). The rest of the diverted water is used for other purposes such as land preparation for the next wet season, domestic washing and bathing, and livestock watering. It appears that actual dry season abstractions are unnecessarily large, and could be cut drastically, while still satisfying crop water requirements and other dry season uses.

Table 3 Calculated net irrigation demands in Usangu

Period	*Result*
Wet season (Dec-May)	
Total flow volume in rivers (Mm^3)	1508.5
Total net irrigation demand volume (Mm^3)	376.1
Net irrigation demand as % of river flow volume	25%
Dry season (Jun-Nov)	
Total flow volume in rivers (Mm^3)	283.9
Total net irrigation demand volume (Mm^3)	80.2
Net irrigation demand as % of river flow volume	28%

Changes in river courses, natural or man-made, that cause the diversion of rivers into fan swamps or onto alluvial fans, where large losses can take place by evaporation or percolation, also contribute to reduced inflows to the Eastern Wetland. Historical changes to the courses of the main perennial rivers in Usangu are documented in Table 4.

Table 4 Known historical channel changes to main perennial rivers

River name	*Year*	*Natural or Man-made*
Mbarali	End of 1800s	Natural
	1930s	Natural
	1995	Natural
Kimani	Prior to 1949	Uncertain
	1949	Partly natural, partly man-made
Gt Ruaha	1955	Probably man-made
	1968	Natural
	1990	Man-made
Chimala	1970s	Man-made
	1990	Man-made
Ndembera	1974	Natural
	1998	Man-made

The reduced inflows to the Eastern Wetland in the dry season, and possibly in the wet season, undoubtedly contribute to the reduced outflows and the eventual cessation of outflow. However, there are other factors, which operate within the Usangu Wetland, which may also contribute to reducing the outflow, including:

- An increase in evaporation from the wetland
- A reduction in the volume of stored water in the wetland that is physically connected to the outlet.

An increase in water loss from the swamp by evaporation could result if, over time, the area of open water increased at the expense of the area covered by swamp vegetation. The difference in annual evaporation between an open water surface and a vegetated swamp surface is about 0.45 m of water in this region of Africa. Although an increase of 8 km^2 in open water area in the perennial swamp was detected during the period 1977 to 1999, this was small compared to the minimum total area, 82 km^2, of the perennial swamp. It is unlikely to be sufficient to cause the observed reduction in outflow.

On the second point, it is thought that the bottom of the perennial swamp may be perched above the outlet. It appears that there is some kind of blockage, either a levee and/or vegetation which is preventing water from draining from the main perennial swamp through the exit in the dry season (Figure 6). In the wet season the blockage is underwater and the water surface extends from the perennial swamp (and from the seasonally flooded area) to the outlet so causing outflow to occur. The blockage starts to act as water levels drop during the dry season, isolating the perennial swamp from the exit. The subsequent drainage of the reduced volume of water held in the minor seasonal wetland would result in the steep water level recessions observed during recent years (Figure 5). This figure shows that dry season recessions have not always been steep, but have developed this characteristic since the mid 1980s.

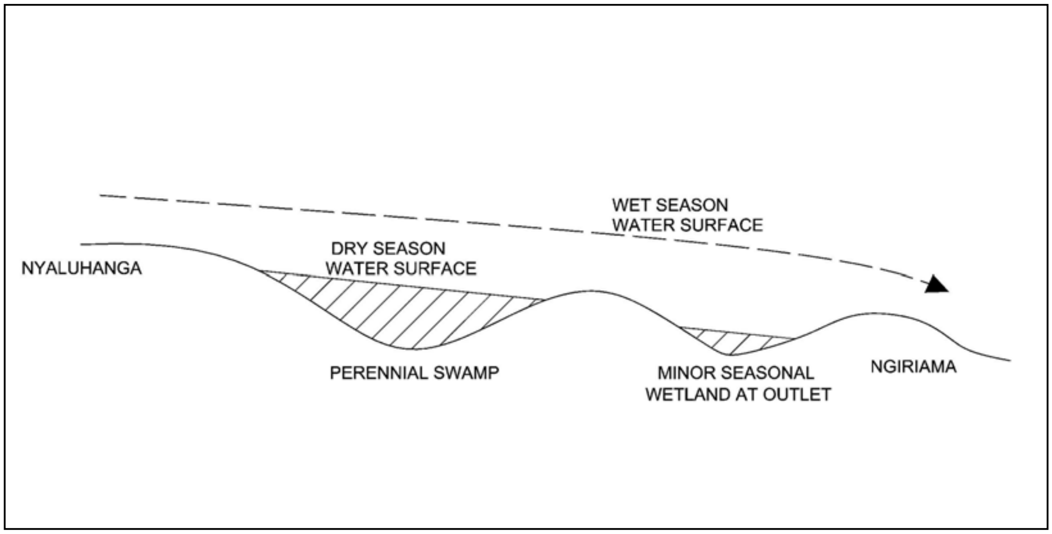

Figure 6 Revised concept of two separated basins in the Eastern Wetland

5. Options for water management in Usangu

Although the hydrological processes within Usangu are only partly understood at present, some initial suggestions for water resources management options are emerging already. These will be refined and added to, as more information becomes available during the coming year.

There should be five major objectives to water resources management in Usangu:

- Increase annual flows to Mtera reservoir
- Restore the low flow regime through Ruaha National Park to an environmentally acceptable level
- Maintain or improve the environmental functions of the Eastern Wetland
- Optimise the production of irrigated rice in Usangu and minimise social conflict
- Provide alternative water supplies for domestic and livestock use in the irrigation areas.

To increase annual inflows to Mtera reservoir it is necessary to increase wet season outflow from the Eastern Wetland. The key to this is reduced evaporation losses obtained by minimising the flooded area of this wetland during the wet season. This could be achieved by canalising the Great Ruaha River by the construction of levees to convey the inflow past the perennial swamp to the outlet at N'Giriama.

To restore the low flow regime in the Great Ruaha River downstream of Usangu it is necessary to increase low flows in the dry season to the outlet at N'Giriama. This may be achieved by three possible actions:

- Removal of blockages to enable water to flow from the perennial swamp, where it currently evaporates, to the outlet;
- Construction of a low weir at the outlet which slightly raises the dry season water level in the wetland and which would regulate, by means of a control gate, the release of sufficient compensation water downstream;
- Restoration of dry season inflow to the Eastern Wetland through Nyaluhanga by reducing upstream diversions into irrigation schemes and evaporation/percolation losses in fan swamps and on alluvial fans.

To undertake the third action, certain specified perennial rivers could be designated as ”red routes” for which particular measures could be introduced to enable as much water as possible to flow down them during the dry season. Drainage lines and river channels should be regularly checked for unlicensed abstractions and blockages. Boreholes or piped water supplies should be introduced to villages lying alongside major abstraction canals, so there would be no essential need for the canal to be kept flowing during the dry season for domestic or livestock water supplies. Dry season irrigation abstractions should be minimised, perhaps by scheduling them on a one-week-on, one-week-off basis, so that they allow regular release of compensation flows.

A brief review was conducted of the potential for groundwater to maintain the flow in the Great Ruaha River as it flows through the Ruaha National Park. Typical yields of boreholes in the geological formations in this area are of the order of 1 or 2 $l\ s^{-1}$. These would be sufficient to provide a practical method to keep strategic waterholes available for animals in the park. Another possible source for those waterholes along the course of the Great Ruaha River and/or its tributaries might be sand dams. But in order to use groundwater to maintain a minimum flow of, say, 1 $m\ s^{-1}$ in the main river channel, over 500 boreholes of this capacity would be required, which is a totally unrealistic proposition.

The environmental functions of the Eastern Wetland are not yet fully understood. In addition to the water storage/conveyance/loss process, uses of the wetland include dry season grazing, fisheries, opportunities for regulated hunting and provision of wildlife habitat. A research study on the functions of the wetland is to be carried out in 2000, which would enable decisions to be made on the economic benefits of maintaining the wetland ecosystem or not. If it is decided to maintain the environmental functions it may be necessary to control the future use of fertilisers and pesticides upstream, and ensure no further reduction in river inflows, which might eventually lead the perennial swamp to develop into a seasonal one.

To optimise production of irrigated rice in Usangu and minimise social conflict, two proposals are suggested:

- Establish a pilot river management system on a single river based on a water users association;
- Transfer the management of irrigation on the large state farms from the farms’ own staff to the smallholders who currently rent many of the plots.

Both of these proposals are aimed at maximising ”crop per drop” by making more efficient use of the water that is currently available, The main aim of the pilot scheme is to achieve an equitable distribution of irrigation water between top-enders and tail-enders both on each furrow and on the river itself. If, in addition, flows can be maintained downstream this will contribute to restoring the low flow regime in the Great Ruaha River and/or improving the environmental functions of the Eastern Wetland.

The ultimate aims of the proposal for irrigation management transfer is to save water upstream, increase rice production and enhance rural livelihoods. Many of the fields on the large state farms have been rented out to smallholders, but the actual water management is still retained in the hands of the farm employees, leading to inefficient distribution within the scheme, and ultimately to over-abstraction from the rivers. It is proposed that the smallholders have a much greater voice in the control of the internal water distribution, so that they can increase their own production.

6. The way forward

There is still much to be learned about the way the Usangu Basin functions hydrologically, and the scientific work is continuing. However, the real challenge will be integrating the science with the social and political aspects. The focus of the project has already shifted to building the capacity of the stakeholders to develop resource management strategies. It will not be possible to satisfy fully all the competing demands on the water resources of the Usangu Basin. Inevitably, some political decisions will have to be made, but these can now be made on a scientific basis.

7. Acknowledgements

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