Pre-complete copy of this paper - not for quotation. Correct citation for published article:

Lankford, B. A. 2001, Red Routes On Blue Rivers: Strategic Water Management for the Ruaha River Basin, Tanzania. *Water Resources Development*, Vol 17, No.3: 427-444.

**Lecturer in Natural Resources, School of Development Studies, University of East Anglia, Norwich, NR4 7TJ, UK*

Abstract
Allocation of water in river basins not only requires the setting of targets of water supply to different users, but also the establishment of appropriate strategies to achieve those targets. As an example of this, "red routes" – an idea taken from a plan used in the city of London to ensure free-flowing traffic on key arterial routes – is proposed for the Ruaha basin in Tanzania. The paper argues that allocation of water is best achieved by managing key rivers (red routes), rather than all rivers, and by concentrating on part rather than the whole of the annual calendar. In this way, the principle of 'zoning' is employed to utilise comparative advantages found in some rivers and not in others. This strategic approach selects from the main theories of water management; command and control, technical, economic, and community-based activities. It also uses, in part, a rural-livelihoods justification for re-allocation. This strategic approach fits the hydrological situation of both use and supply of water and has clear objectives in mind, proposing the necessary management activities to deliver the objectives.

Introduction
River basin management incorporates an integrated approach to water supply and demand within a river basin, often deemed to be a natural unit of water management:

> "The river basin is seen as a means for developing an integrated approach. Its closed geographic boundary system permits various sectors and users in a basin to work together: agriculture, flood control, industry, settlements, and communities". (EC, 1998)

In tropical and sub-tropical countries, a key part of re-allocation of water is the ability to reduce the demand of water from the irrigation sector. The argument is that such is the magnitude of irrigated water use, that even small releases could provide significant benefits to other users. Yet solutions are not readily available. There are difficulties in applying economic and privatisation forces upon irrigation systems; of scaling up common property management mechanisms from within irrigation systems to across the river basin to more than one irrigation system; of applying "command and control" approaches (Morris et al, 1997); or of applying out-of-fashion technical solutions. Individually these might not succeed, yet a flexible approach that mixes solutions taken from different theories of water management, 'zoned', focussed and 'fit' to the situation at the level of the river and irrigation system may provide the best means to redress water use patterns for large-scale surface water systems. The 'red routes' notion in this paper details how such a 'strategic' approach at the river level is more situationally focussed and suited.

Strategies for river basin management in the Usangu arose from interdisciplinary studies being conducted for the UK Department for International Development (DFID) by the team working on the project; "The Sustainable Management of Usangu Wetlands and their Catchments" (SMUWC) on the Ruaha River in Southern Tanzania. The project started in 1998, with a three-year time frame. Based in Mbarali District, it reports to the Rufiji Basin Water Office, of the Ministry of Water, and to local district councils. The project resulted from concerns over the management of water and other natural resources in the Usangu basin, particularly when water shortages caused electricity cuts in Dar Es Salaam during the nineties. The case study is described in brief below, and in articles by Kikula et al (1996), Lankford and Franks (2000), Baur et al (2000) and in reports by the consultancy team (SMUWC 2000 a to e). Hazelwood and Livingstone (1978) can be consulted for an historical perspective.

The case study
The key difficulties with water management in Sub-Saharan Africa arise from the common characteristics found in the rivers basins here; size, scale and distances involved, lack of groundwater, seasonality of rainfall,

communications and road access to name a few. Carter (1998) notes some of these in his analysis of river basin management into Nigeria.

The Ruaha River basin reflects some of these characteristics. Found in the upper catchment of the Rufiji Basin in southern Tanzania, East Africa, the river has a catchment area of 22,000 km^2 consisting of a central plain surrounded by high mountains to the east and south, and lower hills to the west. Figure 1 shows a schematic of the Usangu Catchment with the 11 major sub-catchments that have been delineated in the area.

There is one rainy season a year from mid-November to April during which rice is grown. Rainfall is approximately 1500 mm per annum in the upper catchment and 600-800 mm per annum in the central plains. The upper catchment is the source of the rivers that all supply the Usangu Wetlands, a permanent swamp of approximately 50-80 km^2, from which the Ruaha river discharges. There are five larger perennial streams, namely, the Chimala, Ruaha, Kimani, Mbarali and Ndembera, plus eight smaller perennial rivers. There are also a large number of seasonal streams.

The basin has seven inter-connected users of water, as Table 1 indicates. In the upper catchment, there are rainfed farmers and farmers conducting irrigation of maize and vegetables. It is thought that water use here is relatively minor, and has not been altered to any major extent via land use change. On the footslopes of the escarpment and plains, basin-irrigated rice systems are found (see Figure 1). Approximately 40,000 hectares of rice are grown during a normal-to-wet year when statistically average weather conditions occur and when irrigation is essentially supplemental to the water provided by rainfall. In a dry year, the core irrigated area much less at 22,000 ha, utilising mostly river flows with little reliance on rainfall.

Figure 1. Red routes in the Usangu Catchment

Table 1. Comparisons of water used and production values

Main user of river water	Net Water required	Gross water used	Area, yield or other production function
(Available for use from Usangu rivers upstream of Mtera/Kidatu is approximately 85 cumecs)			
1. Rainfed production	500 ETo mm over 670 km^2 area	*Not part of surface water system*	Total production unrecorded
2. Irrigated rice and crop production	15 cumecs	26 cumecs	40 000 ha rice, 100 000 tonnes pa, 75% of national production
3. Villages/ domestic water requirement	0.5 cumec	1 to 3 cumecs	210 000 people & livelihoods supported.
4. Livestock	0.1 cumec	1 to 3 cumecs	320 000 head = sales produce 41% of total local district tax revenues
5. Environmental – Usangu wetlands	4 to 5 cumecs to maintain core area of 80 km^2	5 to 10 cumecs for increases in area to > 80 km^2	Fish-based livelihoods (300 people, 700 tonnes catch/year) Environmental & biodiversity functions Estimated to be less than 1% of Tanzania total permanent wetlands area.
6. Environmental – Ruaha and other riverine stretches	1-3 cumecs	3 to 4 cumecs (seepage is estimated)	Numbers visited Jobs involved Dollars income (figures unknown)
7. Mtera/Kidatu (proportion from Usangu)	33.6 cumecs	50 cumecs (inc evaporation from dams)	51% of national production in 1997 284 MW capacity

(N.B. Flows are annualised averages, gross water used includes net water and losses to provide net water to certain points in irrigation/hydrological systems. Current Usangu flow at Mtera/Kidatu left over is 85 cumecs - 45 cumecs = 40 cumecs. This is annualised shortfall of 10 cumecs, assuming normal conditions apply. **Sources: SMUWC Reports 2000a, 2000b, 2000c, 2000e,**

The evapotranspiration during the 300-day rice cultivating season is approximately 1600 mm making the deficit between this and effective rainfall nearly 1000 mm. June to October is generally very dry and is the cooler part of the year. The main rice-growing season is now quite extended, and for the purposes of modelling water use is from 2nd dekad in October to 1st dekad in August. Dry-season irrigated cultivation (beans and maize) overlaps in the cropping schedule but is minor in extent at around 2500 ha.

There are approximately 120 irrigation intakes found on these rivers in the Usangu area. These account for an estimated maximum abstraction of 45 cumecs when river flows are near their maximum. This is approximately 31% of the total volumetric inflow of water during a normal-to-wet year, but 47% during a dry year. More pertinently, during the dry season, the abstractive capacity of 45 cumecs far exceeds the average incoming supply of 17 cumecs.

Thirdly, also on the escarpment and plains, villagers require domestic water. The net amount of water required for these users from surface water is small - probably less than a cumec for the whole basin, but gross supplies used in supplying water to villages via canals can be considerable, perhaps more than three to five cumecs.

On the plains, pastoralists require drinking water for their livestock. From the 320 000 livestock thought to be on the plains (SMUWC 2000a), it is thought approximately 100 litres/sec is used by livestock, or less than 1 % of that required by the rice.

Further downstream are found the permanent and seasonal wetlands. These have intrinsic wetland functions (see for example Hollis and Acreman, 1994). It is thought that the permanent wetland of 80 km^2 evaporates approximately 4 cumecs on an annualised basis - though this increases as the wetland expands to over 1000 km^2 during the wet season.

Below the Usangu Wetland is the Ruaha National Park through which runs the Ruaha as the main source of water for animals. National and foreign tourists, the latter paying entrance fees in US dollars, visit the Park. Water requirements are difficult to estimate, but estimates suggest a minimum of 1.5 to 4.0 cumecs in order to meet seepage into the sand riverbed and flow for the length of the Park.

Lastly, TANESCO, the national electricity generating company owns and operates the Mtera/Kidatu hydroelectric power (HEP) generating reservoirs. In the past these supplied approximately 80% of the nation's electricity though this has now decreased to 51%. Reservoir evaporation and releases to generate electricity require substantial volumes of water much of which is captured during the wet season.

Water competition between users

It was previously believed that rice was in direct competition with the replenishment of the HEP storage reservoirs. However a number of analyses indicate that this is no longer the case. Instead the role of climatic fluctuation plays an important role; in normal to wet years, irrigation uses approximately 30% of water available for downstream use, whereas in the 1-in-5 drier years, irrigation utilises nearly 50% of all water.

However, since 1992/93, the previously perennial Great Ruaha River has dried up during the period September to December. Surveys of the rivers that feed the wetland reveal that flows reduce during the dry season, and that during mid November to December, the rivers dry up completely. Analyses suggest that rivers are far more sensitive to drying up in the dry season than the wet season. This is a result of composite effects – these rivers are utilised by dry season non-rice crops, domestic and livestock water demand, watering of fields in error, and watering on purpose for duck hunting, fishing and, starting in September, for field preparation in readiness for rice transplanting.

The current approach to reallocation of water in Usangu

There are currently two main approaches to water control. A sectoral approach to improving irrigation efficiency is one method, whereby irrigators are encouraged to save water via better irrigation management so that these savings pass downstream. These efficiency gains are supposed to come from both technical fixes (e.g. adjustable intakes) and management fixes (e.g. changes to water distribution). Such approaches seem popular among donor agencies under the guise of smallholder improvement projects (e.g. DANIDA, 1998 and RBMSIIP quoted in the project Memorandum, DFID, 1998). However, it is not clear to what extent these past interventions have improved irrigation efficiency. In fact, water demand has been increasing, due to expansion of rice and upgraded intakes, from approximately 10 cumecs in 1980 to 45 cumecs in 2000. Indeed, without additional safeguards, any saved water tends to be used by other irrigation systems in the Usangu area by the continuing growth of the area under irrigation.

Command and control is the other main approach, providing formal non-tradable water rights to water users that then must be paid for. The promotion of water rights and fees is found in much water resources literature (World Bank 1993, pp 44-53). These rights are flow rate based (e.g. 0.6 cumecs), and focus on wet season rice – though rights are halved for dry season period. The Rufiji Basin Water Office (RBWO) has records for 300 water intakes in the Usangu area, each of which will eventually, according to current policy, require a formal water right. (These intakes are on rivers and on drainage lines being tapped by irrigators peripheral to other irrigation systems).

While water rights appears elegant (a simple flow rate) and may have worked in other countries, it may not be the most appropriate in the Usangu Plains. This is because of a number of reasons. In some cases, the water rights are simply water duties (the command area multiplied by 2.0 l/sec/ha) without being reconciled with available water or with downstream needs, in which case such water is not effectively available. In other cases, rights are not determined in a transparent way; they are not related to the command area or crop water requirement, but instead appear to be based on traditional rights, de facto rights, whatever is available during the peak flow period, or otherwise unexplained means.

In addition, because river flows change dramatically from dry to wet seasons, and from wet years to dry years, a fixed right works only in a few circumstances. In other words, the fixed right might be suitable for a 'statistically mean' year. In drier years, the water right will be too much for the available water, yet the 'right' legitimises the practice of abstracting all the water in the rivers even when the latter are left dry. Conversely, for wet years, the right is less than the available water, and probably less than the actual abstracted amount.

Relating water use to right is problematic as water is unlikely to be ever metered and monitored, and so farmers may take more than their right. Furthermore, with a fixed payment, farmers will not use the marginal rule. In fact having paid for a right, farmers might be inclined to use more water than necessary.

RBWO resources (staff and transport) to monitor water use are restricted and are unlikely to increase, and access during the rainy season is difficult. Fees are rarely paid to RBWO, and so do not provide resources needed for their management of water. These constraints mean that, as evidenced by a recent and comprehensive survey (Gillingham, in 2000b), most farmers do not have - or are not aware of – their formal rights.

The final response to 'failure to pay' involves locking of gates. Locks can be difficult to set for some gates and can be broken. Policing of a locked gate involves additional resources. Furthermore, such actions can make future engagement with the irrigation community more problematic and are less likely to encourage self-control by the users.

In effect, the resources available to implement the current vision of the RBWO are insufficient, and the strategy itself is questionable in terms of its intended outcomes. Howe (1996) also questions non-tradable permits under conditions of water scarcity.

A seasonal focus on water management

In order to draw up a more focussed strategy, it is necessary to understand the seasonal variation of supply and demand. Table 2 shows that three main periods exist. During the first 'highly stressed' period, November to early to mid January, irrigators urgently need water to begin their rice nurseries and field preparation, yet rains and river flows have not picked up enough to meet and surpass this need. It is during this period that the rivers below intakes are frequently found to be dry.

Table 2. Seasonal variation of water demand and management

Period	Season	Dates	Hydrologic characteristic	Implications for flexible approach	Institutional focus
1	Late dry season/ early wet season	Nov to mid Jan	‘Highly stressed’ Demand >> supply	Accept shortfalls in basin wide allocation, but set targets for staged compensation flows (see below).	Local water users with external RBWO adjudication
2	Wet season	Mid Jan to end May	‘Wet’ Supply >> demand	Allow for natural allocation of water.	Local user monitoring with little RBWO involvement
3	Dry season	June to end Oct	‘Managed balance’ Supply = demand (*Red routes*)	Irrigation interventions. Technical demand & supply side solutions. “Red routes”	Local user monitoring with external RBWO monitoring

In the second 'wet' period, from early to mid January to May, the rains arrive leading to substantially increased river flows. Apart from exceptionally dry years, the rains and river flows together provide enough water for both the irrigators and downstream users.

The third ‘managed balance’ period is during the dry season, from June to the end of October. *Reasonable* gross crop and domestic water demand is thought to be less than 40% of total river supply, yet currently intakes are left open leading to much higher gross water use, which currently takes most of the available river supply. This gross demand is used to distribute water to tailend and other localised points of water demand, to irrigated late-season planted rice, and to wet up land for the next rice season. Also water is abstracted and spread onto bare fields or into the bushveld mainly because of neglect and because such water is used by fisherpeople and duck hunters to provide better conditions for their 'catch'.

Strategies for allocating water

A review of options for allocating water was conducted by SMUWC (2000c). These are listed below under four main headings as they apply to the situation in Usangu Plains. Some of these are utilised to construct the 'red routes' policy, discussed later.

'Do nothing' strategies

During the 'wet' period (the second period discussed in Table 2), it is more efficient for the RBWO to 'do nothing' and rely on the natural re-allocation that occurs when water supply exceeds demand. This happens during the mid- to later rainy season in Usangu, from approximately mid January to May. The rains bring much greater river flows and reduce field water demand. The RBWO has a diminished role during this time as the process and scale of natural allocation of water is far greater than could be achieved by managing and monitoring intakes and water rights. However, even if this becomes a 'do nothing' period, it may still be sensible to ensure no additional abstraction structures are constructed or upgraded in the Usangu Plains so as to protect flows for the Mtera/Kidatu storage reservoirs - if that is decided by the stakeholders, national and local.

During other times of the year, it may be necessary to accept severe shortfalls in re-allocation. This is another case of ‘do nothing’ except here demand greatly outstrips supply. This happens during the first period, mid October to mid January, when fields are being wetted up for rice. The argument behind this ‘do nothing’ is that such is the intensity of water need that no external agency may be meaningfully intervene to ensure compensation flows above a token gesture amount to ensure some environmental maintenance downstream. However, this does not preclude the agency playing a useful role in mediating internal conflicts between intakes within a sub-catchment and within irrigation systems, and ensuring some downstream compensation flow.

Furthermore, this second ‘do-nothing’ idea is predicated on the notion that for each downstream user there exists some buffering to low and zero flows. In other words, the Usangu Swamp, the National Park and TANESCO can go a certain period of time - specific to each user - without supply. This buffering capacity depends on the amount of storage and nature of demand of water by the user. The emphasis here is on the time involved; for example a long and lengthening period of zero flow in the Ruaha is far more deleterious to wildlife than a short, but nonetheless highly visible period of zero flow.

Technical solutions
A number of supply side solutions have been proposed in the area (Riddle and Issae, 1993, SMUWC 2000c). Here the argument is that increased storage or access from groundwater will solve shortages in water supply. However, both of these are problematic in the Usangu area due to a lack of suitable and economical sites and absence of a significant aquifer. Nonetheless, more appropriate ideas of local supply-side solutions do exist, such as; boreholes for domestic users in Usangu, boreholes and sand-dams for the Ruaha National Park and design alterations to increase HEP storage capacity.

A number of technical demand side solutions exist to reduce water use above the Swamp. These include: installing piped and borehole domestic water supplies to reduce canal conveyance of water; installing diversions in rivers where needed to reduce losses into intermediate swamps; ceasing the upgrading of intakes; reducing the maximum capacity of selected intakes; altering canal layouts; installing drains from areas below irrigated areas to rivers; and checking of drains and river channels for blockages. While these represent technical solutions, they should be seen as negotiated solutions within a water user engagement process.

Community, institutional and legal solutions
Common property solutions are being closely examined by the project. By enabling local communities to control water, water control is more efficiently passed to users. SMUWC has proposed a river users association (termed a sub-catchment resource management programme (SRMP) (Devitt and Gillingham in SMUWC 2000b). This idea encourages common property mechanisms within irrigation systems and also brings users from different irrigation systems together to reconcile water use within a sub-catchment of the large Ruaha catchment. In this way, users might share existing water between intakes and more importantly agree upon restrictions on the command area utilised for irrigation. This is an important scaling up of common property resource solutions to the catchment scale, but success at these and still larger scales has yet to be observed.

Alongside the river users association discussed above, refinements to the issue of water rights could be made. For example, the existing fixed intake right could be replaced by ‘sub-catchment water rights’ where one river water right is negotiated amongst the users.

In addition to this, proportional water rights are being considered. Here, users negotiate with the RBWO and other users on the river an abstraction based on a proportion of whatever the flow is in the river: for example, taking 10%, or taking 45% of the available flow regardless of the change in flow. By using appropriately designed intakes, the agreed proportion could be abstracted for both low and high flows. This kind of initiative would need further technical re-design of intakes to ensure an acceptable transparency of division of flows. A repeated design down the river, termed ‘castellated weirs’ (see Figure 2) would enhance transparency of abstraction between intakes.

As Franks (SMUWC 2000d) suggests, providing other sectors with water rights gives RBWO a wider non-rice perspective on claims for water and allows them to manage water accordingly. Examples are the passive water users such as livestock keepers, fishermen, the Usangu Game Reserve, the Ruaha National Park and TANESCO. At present, they require water but are not provided with water rights.

It may be possible to consider water right payments in kind. This idea suggests that cross-seasonal water payments be made in water rather than money on the basis that water has differing values at different times of the year for different users. The idea goes alongside the three-season analysis discussed above and in detail in the next section. Water users would ‘pay in water’ by not taking water during the main part of the dry season (June to November) in order to be given greater access to water during late dry season and the early part of the rainy season when water is more critically needed. In a sense, users would not pay money for rights, but accept some discipline when water is restricted. This acknowledges that paying in cash for water is unpopular among farmers.

Periodic reviews of water rights are recommended as a part of the flexible strategy so that changing conditions of supply, demand and cultural and economic priorities may be met.

Economic solutions
The theory here is that water markets enable users to bid or pay each other for water so that its price reflects its value, resulting in water use controlled by cost-benefit decisions. However, both centralised and decentralised water markets are unlikely to play a major role in the near future, but are not discounted altogether. A centralised system is most unlikely to work in Usangu because of variable nature of water supply; the large distances involved in communication; high transaction losses due to evaporation in the Usangu swamps; a lack of flow monitoring; and weak financial structures to support bidding for water.

However, decentralised payments might function where tailenders within the hydrological system pay upstream users to release water. For example, the fishermen on the Usangu swamp could be paid by the Ruaha National Park to keep swamp channels open to maintain the throughflow of water.

Red routes - introduction
The term “red routes” is an expression taken from traffic control in London where measures are used to keep key selected roads flowing freely (TDFL 1993, 2000). This effectively zones some roads and allows traffic staff to concentrate their effort accordingly. In the Usangu, the objective of red routing is to maintain a minimum flow into the swamp during the dry season from key upstream rivers. The red-routes idea is essentially a dry season command-and-control 'zoning' concept applied to some Usangu rivers in an attempt to use RBWO time more efficiently during the 'managed balance' part of the year to ensure compensation flows within key rivers at key times. It signals to stakeholders that some rivers feeding the swamp are markedly different from each other in terms of supply and demand of water resources.

The principle of zoning in natural resource and water and wetland management is well founded (Ramsar Convention Bureau 2000 and Ministry of Environment, Water Resources and Legal Amazon, 2000). It acknowledges that certain localities have different natural endowment or use characteristics, and needs to be managed accordingly.

Selection criteria for red routes
Since the emphasis is on cost-efficient management during the dry season, certain rivers in the plains are unsuitable. Seasonal rivers are not red routes as their regimes are dynamic and unpredictable. They have no flow during dry season and are highly responsive to the wet season rainfall events. Irrigation is opportunistic and intakes are often traditional in design, often changing in location; are abandoned and added to; and flow rates through them fluctuate considerably.

Perennial rivers with many intakes and a history of dry season irrigation are not selected. The high numbers of intakes makes these rivers difficult to monitor. In a sense, these rivers are unlikely ever to supply the swamp during the dry season in the future. For example, the Chimala, which has much dry-season irrigation and discharges into an intermediate swamp is an unlikely candidate. The eight perennial streams of the Mkoji catchment are not ideal; they feed 70 intakes, have extensive dry season irrigation and are heavily utilised during this period by many farmers.

Red routes are perennial rivers with few intakes, where natural losses can be minimised, and where dry season irrigation is poorly developed and can be further controlled by informal or formal legislation. Four candidates arise: Kimani, Ruaha, Ndembera and Mbarali, presented in Table 3. These four rivers account for approximately 22 cumecs of abstraction, which is 49% of the intake capacity found in the Usangu area. The red routes also supply approximately 50% of rice area during a normal to wet year, but only 25% of dry season (non-rice) cropping. Importantly, they only have 15 intakes on them, which constitutes 13% of the total number of intakes in the Usangu Plains. With this proportionally small amount of dry season cropping, there is no reason why the river supplies should not be enough to meet the small net demands arising from within the irrigation systems on these rivers, yet provide significant dry season flows to downstream users. In essence, this strategy reduces the need to manage the 120 intakes found in Usangu for 52 weeks of the year, to 15 intakes for 22 weeks of the year.

Setting objectives of red routes - staged water releases

While the ultimate objective might be to ensure a minimum flow in the Great Ruaha below the Swamp, a more pragmatic basis for the success of the initiative might be a duration target of zero flow. This recognises the pressure on water resources upstream of the swamp, particularly in November. Such a target might be, for example, 'zero flow in the Great Ruaha for no more than 2 weeks'. This requires a minimum discharge in the rivers upstream of the swamp. A staged series of flows in these rivers might be recommended, e.g.:

- A minimum total flow of 9000 l/sec during April to 1st June when the red route intake gates are partially closed.
- A minimum total flow of 4000 l/sec during June to end October when the red route intakes are partially closed even further.
- A minimum total flow of 500 l/sec from early November to mid January, when intakes are opened up to allow irrigation, yet rainfall may not have arrived.

These flow rates are indicative. Further research is needed on the size of the flow needed to keep the Ihefu swamp flowing. The size and staging of such flows, while not being sufficient to maintain a continuous flow below the Swamp, might be critical in keeping the swamp 'topped up', ready to spill once flows increase in December.

Managing red routes

The strategies for managing the red routes are described below though it is likely that each river needs to be tackled separately taking into account the nature and pattern of water use. The four red routes would be subject to greater attention by water officers during June to November. It is believed that the intake gates could be partially closed with farmers' agreement, from 1st June to 1st November. It is important to recall that dry season cropping is almost non-existent and that net water demand is for domestic needs and rice nursery preparation. This change would be have to be carefully managed requiring new dry season water rights and appropriate fees to be drawn up. Boreholes in affected villages might have to be installed to meet domestic needs currently supplied by surface water.

The main issue is to improve water management during June to July when some water is used for late season irrigation of rice. This will not be easy, and requires new planting schedules and changes to the physical means of distributing water. These ideas are based on existing signs of water control that exist in Usangu including cessation of irrigation before harvesting, siting of nurseries, and construction of canals and in-plot mini-furrows that are used to channel flow through the fields at the end of the season. Reviewing and monitoring cropping patterns would be given priority. Minimal dry season irrigation would be encouraged - as already happens on most of the candidate rivers - so that abstraction is for domestic use and late season rice only.

Irrigation management transfer (IMT) could be applied on the two NAFCO schemes situated on the red routes (see Figure 1). The premise is that this will raise farmer density thereby increasing the 'within-system' competition for water. Apart from saving water via increased irrigation efficiency, IMT could raise yields from the current average 2 t/ha to smallholder yields of 3.5 t/ha. In addition, it could simultaneously provide livelihoods for a greater number of families. Should this option be considered in the future, it is worth noting that peripheral farmers relying on NAFCO drainage water should be given priority to move 'upstream'. Secondly, such a transition provides an opportunity to decrease the overall command area supplied by the intake, so the maximum abstractable flow from the river could be decreased.

Table 3. Possible red route rivers

River	Reason for considering red route status	No. of intakes	Flexible strategies
Kimani	A relatively deep, channelling river. It has only one improved intake, but here operators allow downstream flows and generally close down their abstraction from mid June onwards. Below, a proportion of low flows pass to the Ihefu past unimproved intakes.	5 (1 main one and four small intakes)	Water right to whole sub-catchment, proportional rights, and intakes. Reviews of water rights. Extension advice to reduce water demand.
Ruaha	Currently a spreading river which discharges into the Ifushiro swamp. Water demand in Kapunga could be subject to new controls if irrigation management transfer was introduced, by permanently reducing the command area from 3000 ha to 2000 ha, and having the remaining area rainfed. The Ruaha could be returned to a channelling river if the old course was re-opened, although this requires construction of a diversion.	2 (1 main one, and one minor one)	Irrigation management transfer on Kapunga Scheme, irrigation extension advice, renegotiated lower water right. Technical solutions on Ruaha river to reduce losses to swamps. Improvement of domestic supply via boreholes.
Mbarali	The Mbarali river has one main intake for the Mbarali scheme and two other lesser intakes; Mulla and Igomelo. Mbarali scheme is the oldest state farm; there is comparatively little development of dry season irrigation but there is abstraction for domestic use and wetting of fields. It should be possible to maintain both adequate domestic supply and compensation flows in the Mbarali river.	1 main one, plus two medium sized others	Irrigation management transfer, proportional water right, renegotiated lower water right. Improvement of domestic supply via boreholes. Extension advice to reduce water demand
Ndembera	Until recently, the only remaining perennial river. The new Madibira scheme should be encouraged not to abstract high flows during the dry season for non-rice crops & domestic needs. The Madibira intake is the largest and most significant intake. (In theory, the Madibira intake is shut from May to November – it is important that this remains the case).	1 main one, and assorted others.	Irrigation extension advice.

For the remainder of the year, from 1st November to 1st June (this includes the 'do nothing' periods), the intake gates would be opened, but abstraction would be controlled by adjustments or design of intakes. For the most part, irrigators would be able to abstract what they need.

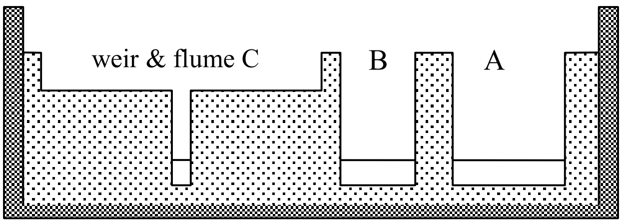
Sub-catchment and proportional water rights could be considered and provided to newly established River User Associations. The proportion of water allowed downstream for the Swamp would have to be carefully set to allow for the necessary compensation flows during the dry season. Proportional intakes (see Figure 2) could be an efficient and transparent way of managing water between intakes (for example see Bellekens 1994). Each intake would consist of a replicated design of weirs plus flumes, with each flume providing water to an irrigation intake on the river plus an additional flume for downstream environmental maintenance. In effect, irrigators from downstream intakes could visit upstream weirs to observe their entitlement by-passing upstream intakes. Proportional intakes have important design considerations in order to work. These are:

1. The widths of proportional flumes needs to be set in accordance to the dynamic supply available in the river, the desired flow rate and the target range of command area.
2. The total width of proportional flumes on the river should be set in accordance with abstractable water supply for the whole river during medium to low flows. In other words, a minimum proportion should be allowed for environmental maintenance and downstream users at low flows. This needs to be agreed by all stakeholders, but in this example it is set at 10%.
3. For higher flows, the level of the by-pass weir height should be set in relation to the flume base levels so that release of water over the weir occurs at the desired river flow rate.
4. The total weir width should be set in accordance with expected flood-return flows.
5. The levels of the floors, and the shapes, of the proportional flumes should be uniform to assist in the transparency of division.

6. Additional on-off shutters could be installed to control flows during June to November on those intakes where minimum flows need to be throttled down further to meet real needs within the command area.

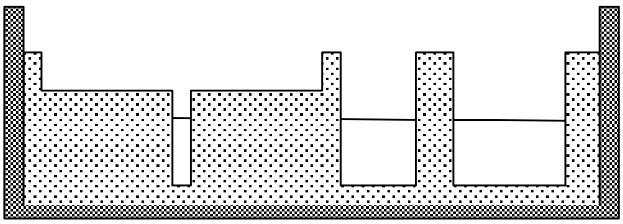
Figure 2. Technical support of water division between intakes - castellated weirs

Proportional division during low flows - November to December



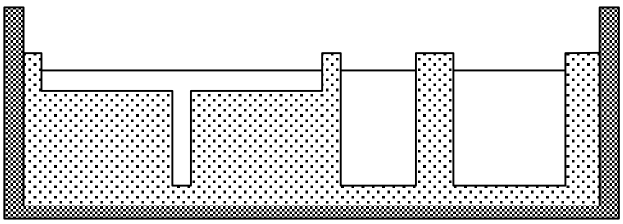
During low flow, design divides according to widths of the proportional flumes, say 50% to intake A and 40% to intake B. Intake A is for an irrigation scheme at the site of the weir, but intake B is for an intake further downstream. The design is replicated at each intake down the river. The small slot (flume C) in the weir is for an agreed environmental flow, in this case 10%.

Proportional division during medium flows - December onwards



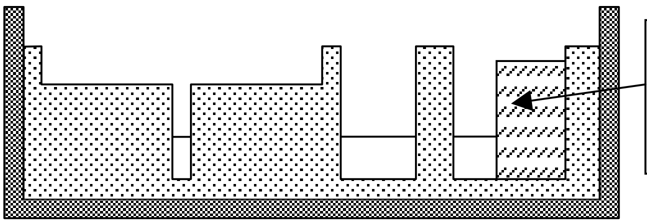
Medium riverflow divides according to widths of the proportional flumes. Proportion remains 50%, 40% and 10% to intakes A, B and the environmental flume

Proportional division during high flows - peak flows during the rainy season



High riverflow divides according to widths of the proportional flumes, and in addition, the weir passes large flows downstream.

Optional one shutter on-off control during June to November (for red routes intakes only)



RBWO reduction in width of intake by adding of one ‘on-off’ shutter to reduce flow during the dry season down to a nominal domestic supply

Implications for theoretical approaches to water management

The notion of red routes in the Usangu Plains raises a number of issues. Firstly, that command and control, perhaps currently out of favour in comparison to market and community-based solutions, has a part to play in Usangu, albeit implemented in a flexible and situation-sensitive way. Nevertheless, secondly, market and community solutions will be important in the region, and their efficacy is being explored. Thirdly, the flexible seasonal strategy implies priority water rights for rice irrigation (or rather of the intakes leading to rice systems) during the wet season, whereas domestic and environmental demands take precedent during the dry season. Howe (1996) presents summarises the benefits of priority water rights.

However, it should be stated here, that resolution of national priorities of rice production, electricity generation and protection of the environment have yet to be undertaken by all stakeholders at the Ministerial, Regional and Local levels. This process is underway at the moment through a number of processes involving newly convened stakeholder institutions and processes (SMUWC 2000d). Whatever the outcome of these deliberations, it is likely that the flexible management strategies described in this paper will be part of the process.

This analysis suggests that a strategic, problem-centred approach to water management rather than the reliance on an application of one theoretical approach over another may improve the likelihood of successful re-allocation of water. The literature on water resources management reveals a comprehensive framework of ideas but which often read as a checklist of options at the river basin, regional and national level. The challenge is to use a flexible approach at the level of the 'river, tributary and irrigation system' to create relevant meaningful strategies applicable to the stakeholders at these lower levels, an objective that Duda and El-Ashry (2000) also argue for. To achieve this, a process of analysing the situation at hand, selecting a mix of solutions from the comprehensive range of options and then elaborating effective lower level strategies is required.

Conclusions

The 'red routes' idea is a possible means by which water is released from upstream irrigation abstractors during the dry season – the period when water competition between downstream-upstream sectors is most visible. ‘Red routes’ describes a flexible, situational, prioritised, targeted, zoned and timed water policy, which may be more appropriate for the Usangu Plains, enabling differing strategy options to be used for each tributary supplying the Ruaha. This strategic approach analyses the situation, cherry-picks from the main theoretical approaches to water management and applies selected strategies to the lower levels of the hydrological system.

The approach marks a shift from a blanket 'fixed rights' approach to one that is prioritised and might have proportionally based water rights. It efficiently concentrates on key rivers rather than all rivers, and only addresses dry season water use when the water balance between upstream and downstream users is more critical. This approach acknowledges the characteristics of the dynamic hydrology of the Usangu Plains, doing nothing (or doing less) when there is an excess or substantial shortfall of water supply over demand. The idea also is predicated upon the argument that buffering exists for each water users, and that staged discharges relate well to buffering capacities.

The strategy acknowledges an increasing livelihoods-reliance on rice as a cash crop, recommending that 'irrigation management transfer' occurs on the government rice farms. However, it also accounts for the livelihood patterns during the dry season when most Usangu farmers turn to non-farming activities. Reducing rather wasteful non-crop watering of harvested fields is central to balancing core upstream needs against core environmental needs downstream.

This policy, now being discussed among stakeholders and the researching team, could fit and build upon local community management concerns and energies for water distribution. This water policy heralds a more flexible approach able to evolve to meet new user initiatives, to respond to changes in water supply and demand, and to incorporate economic instruments in the future. The approach might consider efficient technical solutions when and where possible, and appreciates that these should be locally owned and understood.

Finally, the analysis envisages that source of the ‘problems’ - large abstractions of water from the state farms, play a crucial role in providing the ‘solutions’ to the drying up of the river by playing an important role in providing the necessary dry season compensation flows.

Acknowledgements

SMUWC is funded by the Department for International Development, UK (DfID). The Client is the Ministry of Water, Tanzania. The companies managing the project are Hunting Technical Services, UK in collaboration with Water Management Consultants (UK) and Local Perspectives (Tanzania). Thanks are given to these organisations for permission to present this material. The contribution to the discussion of water resources in the area by other members of the SMUWC team is strongly acknowledged: particularly Tom Franks, Mary Gillingham, Geoffrey King, Nick Mandeville, Lawrence Mbuya, Paul Devitt, Alistair Graham, Jeremy Berkoff, Stan Western, Peter Baur and Tom Boyd.

References

Baur, P. Mandeville, N. Lankford, B. and Boake, R. (2000) Upstream/downstream competition for water in the Usangu Basin, Tanzania. In, *Proceedings of the British Hydrological Symposium, Seventh National Hydrology Symposium*, University of Newcastle 6-8, September 2000. BHS National Hydrology Symposium Series.

Bellekens, Y. (1994) Flow division structures in Bali, Indonesia, in *Designing irrigation structures for mountainous environments. A handbook of experience,* (ed R. Yoder), International Irrigation Management Institute, Colombo, Sri Lanka, pp.157-159.

Carter, R. C. (1998) Prospects for Sustainable Water Management Policy in Sub-Saharan Africa, with Special Reference to the Northeast Arid Zone of Nigeria. In, *Water Resource Management: a comparative perspective*. Ed. D.K. Vajpeyi, Praeger. 107-127.

Kikula, I.S., Charnley, S. and Yanda, P. (1996) *Ecological Changes in the Usangu Plains and their Implications on the Down Stream Flow of the Great Ruaha River in Tanzania*. Institute of Resource Assessment, University of Dar es Salaam, Tanzania.

DANIDA (1998) *Smallholder irrigation improvement*. Agricultural Sector Programme Support. Project Preparation Report. Dar es Salaam.

DFID (1998) *Project Memorandum. Sustainable Management of the Usangu Wetland and its Catchment*, for River Basins Management and Smallholder Irrigation Improvement Project (RBMSIIP) and Ministry of Water, Water Resources Department, Government of Tanzania. Department for International Development, London.

Duda, A. M and El-Ashry, M. T. (2000) *Addressing the Global Water and Environmental Crises through Integrated Approaches to the Management of Land, Water and Ecological Resources*. Water International, Vol 25, No. 1, 115-126.

European Commission (1998) *Guidelines for water resources development co-operation. Towards sustainable water resources management, a strategic approach*. European Commission, Brussels. 352 pp.

Hazelwood A. and Livingstone, I. (1978) *The Development Potential of the Usangu Plains of Tanzania*, Commonwealth Fund for Technical Cooperation, The Commonwealth Secretariat.

Hollis, G.E. and Acreman, M.C. (1994) The functions of wetlands within integrated river basin development: international perspectives. In, *Integrated River Basin Development*, edited by C. Kirby and W.R. White, Wiley, HR Wallingford. 351-365.

Howe, C.W. (1996) Sharing water fairly. *Our Planet*. The United Nations Environment Programme Magazine for Sustainable Development. Vol 8. No. 3. 15-17. UNEP, Nairobi, Kenya.

Lankford, B. A., Franks, T. (2000) The Sustainable Co-Existence Of Wetlands And Rice Irrigation - A Case Study From Tanzania. *The Environment and Development Journal*, Vol. 9, No. 2, 119-137.

Ministry of Environment, Water Resources and Legal Amazon (2000) Conservation Plan for Upper Paraguay River Basin In The Ramsar 'Toolkit': Handbooks for the Wise Use of Wetlands. Handbook 4: Integrating wetland conservation and wise use into river basin management. Edited by F. Parish and S. Mohkeri. Annex: Case studies on integrating wetland conservation and wise use into river basin management. Secretariat for The Coordination of Environmental Matters, The Ramsar Convention on Wetlands, 32 pp.

Morris, J., Weatherhead, E.K., Dunderdale, J.A.L., Green, C. and Tunstall, S. (1997) The Feasibility of Tradeable Permits for Water Abstraction in England and Wales, in *Water: Economics, Management and Demand,* (eds. M. Kay, T. Franks, and L. E. Smith), E & FN Spon, London, 328-338.

Ramsar Convention Bureau (2000) Recommendation 5.3: The essential character of wetlands and the need for zonation related to wetland reserves (adopted by the 5th Conference of the Contracting Parties Kushiro, Japan 9-16 June 1993). In, *Handbook 8. Frameworks for managing Wetlands of International Importance and other wetlands*. Ramsar Convention Bureau, Gland, Switzerland. 60 pp.

Riddle P.J. and Issae A.E.R. (1993) *Irrigation water supply characteristics at Mbarali State Farm Report*. Department of irrigation and Food and Agriculture Organisation, Rome, 11pp

SMUWC (2000a) *Interim Report, Supporting Volume A Land, Supporting Report 2, Livestock,* for Directorate of Water Resources, Ministry of Water, Government of Tanzania, The SMUWC Project, Mbeya Region, Tanzania. pp 80. (Authors: King G. and King A.)

SMUWC (2000b) *Interim Report Supporting Volume A Water, Supporting Report 2, Water Management,* for Directorate of Water Resources, Ministry of Water, Government of Tanzania, The SMUWC Project, Mbeya Region, Tanzania. pp 119. (Authors: Baur, P., Mandeville, N., Lankford, B.A., Gillingham, M., Devitt. P)

SMUWC (2000c) Water Resource Management Strategies for the Usangu Catchment, In *Working Papers June 2000*, for Directorate of Water Resources, Ministry of Water, Government of Tanzania, The SMUWC Project, Mbeya Region, Tanzania. 9 pp. (Author: B. Lankford).

SMUWC (2000d) *Interim Report, Towards a Management Strategy for The Usangu Catchment*, for Directorate of Water Resources, Ministry of Water, Government of Tanzania, The SMUWC Project, Mbeya Region, Tanzania. pp 107. (Authors: T. Franks, G. King, J. Berkoff, and P.Baur)

SMUWC (2000e) Supplementary Planning Report, In *Final Report 2001*, for Directorate of Water Resources, Ministry of Water, Government of Tanzania, The SMUWC Project, Mbeya Region, Tanzania. 42 pp. (Author: J. Berkoff).

TDFL (1993) *Network Plan*. Traffic Director for London, London, UK

TDFL (2000) *Annual Report 1999-2000*. Traffic Director for London, London, UK, 30 pages
World Bank, The (1993) *Water Resources Management. A World Bank Policy Paper*. IBRD. Washington, USA, 140 pp.