2nd WARFSA/ WaterNet Symposium: Integrated Water Resource Management: Theory, practice, cases; Cape Town, 30-31 October 2001

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Integrated water resources management in South Africa: Spreading both wings of the capacity-building eagle

Ola BUSARI

Dept. of Hydrology & Water Resources
University of Venda, Thohoyandou 0950, South Africa

busari@univen.ac.za

ABSTRACT

South Africa's emerging legal, policy and institutional frameworks in the water sector recognize the overall capacity shortfalls for the comprehensive operationalization of the philosophy of integrated water resources management. There is consensus that facilitating integrated learning to meet the capacity building challenges of broadening the existing professional skill base and creating new cadres is of utmost importance. But that represents only one wing of the eagle. On the other wing is the immense responsibility to empower a much wider spectrum of previously (and currently) disadvantaged citizens, whether as individuals or as groups, to meaningfully participate in (and even technically drive) both the platforms and processes for integrated water resources management.

This paper documents ongoing institutional efforts to produce a critical mass of skilled professionals from segments where water sector facilitators are urgently required, within an interest-motivation setting for local action whilst encouraging broad-based coordination and global perspectives. Consonant with the vast nature of integrated resource management, strong inter-disciplinary learning is adopted across areas appropriate to the scientific, technical and managerial functions for effective water resources assessment, development, conservation and management.

***Keywords**: integrated management; education and training; participation and equity*

INTRODUCTION

In South Africa, as everywhere else on our planet, an increasing sense of urgency with regard to the responsible management of water resources for economic development and social and environmental well-being, is encouraging efforts in search of a pathway that effectively engages an intricately interacting complex of forces. Prominent amongst the common critical concerns in several countries are an escalating human and industrial demand; rising competition for irrigation water; environmental degradation; inadequate institutional, legal and regulatory frameworks; and sub-optimal economic growth in the face of global readjustments.

From the quest for a comprehensive and coherent frame for addressing the *spatial, temporal and institutional dimensions* (Institute of Water and Sanitation Development, 1998) of water resources concerns, together with approaches that are consistent with ecological integrity and socio-economic feasibility, has emerged the concept of integrated water resources management. Whereas integrated resource management is widely acknowledged as a sound strategy for sustainable development, activities fully and directly devoted to its implementation are uncommon in practice. Indeed, experience on the implementation of integrated water resources management from all over the world, whether within or outside Africa, shows clearly that countries have adapted vital elements of integration to varying degrees.

One of the more visible threads running through the selective implementation of integrated water resources management is national capacity, including both institutional and human resource capacity for aligning properly with shifts in sector paradigm and for accomplishing strategic objectives in an inclusive and mutually agreed manner. Some of the important indices of capacity-related integrated strategies, the absence of which may be suggesting operational weaknesses in the implementation of integration have been recently summarized by Plummer and Stacey (2000: 295) as follows:

- strategic planning where there is evidence of capacity to prioritize, focus and develop actions to realize goals and objectives;

- interactive planning where there is evidence of multi-stakeholder participation and communication; and

- capacity to facilitate multiple perspectives where there is evidence of organization evolution and maturation in response to changing circumstances (Lang, 1986; Carley and Christie, 1993; Loomis, 1993; Mitchell and Shrubsole, 1997).

In adopting integrated management, South Africa's Water Policy (1997) proposes a "new management approach and organizational arrangement" for ensuring integration across a number of dimensions, whilst pointing clearly to the existence of serious weaknesses in institutional and human resource capacity. Although some progress has since been made in terms of improving the sector's technical and managerial expertise, the legacy of inequities from decades of apartheid policy interventions ensures that there remains a yawning gap in the capacity required to implement the Water Policy.

Water sector capacity shortfall is particularly critical in those areas of integrated management which call for new skills, and more so with respect to the decentralization of water resources development, apportionment and management. Following an examination of the changing needs of the sector in an environment that seeks to pursue equity and corrective action, this paper discusses the evolving capacity in a South African University's School of Environmental Sciences to meet the challenges, within a curriculum setting specifically geared towards integrated resource management.

CAPACITY BUILDING PARADIGM SHIFT I: TOWARDS INTEGRATED WATER RESOURCES MANAGEMENT

Increasing sensitivity to sustainability -- the underlying bedrock of the shift to integrated resource management in South Africa's water sector -- arose from at least three important factors. First, the cyclic drought that ravaged the whole of the Southern Africa region in 1981/2 and 1991/2 served to highlight the limited nature of the water resource and the concomitant need to manage it effectively. Second, this limitation underscored the problematic nature of the prevailing supply-heavy resource development approach, easily synonymous with the engineering works of dams, irrigation and drainage schemes, and boreholes and storage reservoirs, occurring inevitably within the uncoordinated institutional framework of traditionally sectorally organized government departments. Third, and very significantly, in the wake of the sense of urgency witnessed as part of a fresh political dispensation, the country's new Constitution demanded a change in the existing natural resource management practices.

South Africa's shift in its approach to water resource management is comprehensively captured in both the Water Policy (1997) and Water Act (No. 36 of 1998). The intention is clearly documented as to "manage the quantity, quality and reliability of the nation's water resources to achieve optimum, long-term, environmentally sustainable social and economic benefit for society from their use." In particular, the National Policy introduces a number of integrated water resources management elements to systematically address the problems of the previous sector alignment, especially equity of access to the resource and to benefits from its use, the sustainability of resource use, and mutual cross-border cooperation to optimize regional benefits. The key elements adopted include:

- recognition of the hydrologic cycle in its entirety, including its connection with the ecosystem and the inherent need for resource protection;
- characterization of water as a national resource, enabling national management covering the widest range of interests and uses;
- limitation of water rights in perpetuity; and differentiation between, and de-linking of, water rights and land rights;
- allocation of water specifically to achieve social and economic optimal use;
- definition of decentralized institutional frameworks for ensuring the participation of stakeholders in resource management decision making;
- requirement for demand management emphasizing water conservation and the pricing of water as an economic good; and
- confirmation of the special need to fulfill the rights of neighbouring countries, as well as the obligations to them.

The implications, for capacity building, of the foregoing sector reform are two-pronged, even if intertwined. The first relates to the spread of, and inter-linkages between, organizations and institutions to be involved in capacity building initiatives, and the other concerns the types and numbers of professionals requiring targeted education and training. Decentralization and increased stakeholder participation, for instance, will lead to the emergence of several local non-governmental organizations advocating and promoting the interests of stakeholders, as well as of new semi-government and private enterprises taking on a range of service delivery functions. Viewed against this backdrop, tertiary sector education and training institutions in South Africa, most of which still follow the conventional streams that characterize academia everywhere, will need to do a little more than just updating their curricular to reflect vital missing elements of integrated water resources management. Also, although water research in South Africa is advanced by any standard, there is need for greater diffusion of knowledge from research into practice, and for increased attention to the design of helpful decision support systems across the gamut of integrated resource management.

CAPACITY BUILDING PARADIGM SHIFT II: TOWARDS EQUITY IN SECTOR CAPACITY BUILDING

The capacity building dimensions highlighted in the foregoing section for meeting the requirements of integrated water resources management in South Africa are compounded by the legacy of inequities from decades of apartheid policy interventions. Perhaps more than in most development areas, water sector training and skill development for members of disadvantaged ethnic groups have been seriously compromised by the twin factors of pre-tertiary academic weaknesses and poverty-propelled tertiary drop-outs. Expectedly, therefore, the employment of black South Africans in certain water sector areas (particularly in the public sector) is at a low level, and is worsened by the currently high demand and higher remuneration in the private sector.

A productive environment for learning is yet to be achieved in most of the high schools in the Northern and Mpumalanga Provinces, *inter alia*, with English language communication skills, a strong factor in matriculation examination success, remaining very poor. With a weak mathematics and sciences base, largely because less than half of teachers in these areas are adequately qualified, there is only a small pool of high school graduates who are ready (and willing) to enroll in water-related programmes. And worse still, historically disadvantaged higher institutions are replete with cases of black undergraduates withdrawing, even in these post-apartheid times, from important science and technology programmes simply on account of financial difficulties.

Even if only propped on the fact that sustainable sector development can only occur fast where equity is entrenched, reaching a critical mass of blacks previously excluded by deliberate apartheid polices should form the cornerstone of any serious attempt to produce skilled professionals. It is beyond debate, for instance, that very important lower-level sectoral structures such as the new array of Catchment Management Agencies can ever take off, let alone function meaningfully, unless the requisite technical and managerial capacity is built amongst previously disadvantaged groups.

At the core of all efforts to build capacity in the water sector should be the identification and strengthening of institutions and practices for operationalizing the principle of equity and equitable access. On their part, education and training institutions with a mission to provide skill development for members of previously disadvantaged groups, are already taking the initiative to take insufficiently prepared high school graduates through a one-year bridging programme.

OPPORTUNITIES FOR HOLISTIC SECTOR CAPACITY BUILDING: A SOUTH AFRICAN EXAMPLE

Considering that a great proportion of *water sector professionals* are graduates of predominantly engineering-oriented university departments, there is a huge temptation to believe that the only challenge in South Africa is to facilitate some exposure to non-traditional water sector subject-matter in the curricular of education and training institutions. Yet, in an attempt to accommodate as much *hardware* issues as possible, very little room is left in such programmes to teach even the closely related modules in hydrology and hydrogeology to any depth at the undergraduate level. At the postgraduate level, however, with typical (new) examples at the University of Western Cape and University of Pretoria, programmes addressing several areas of integrated management are increasingly being mounted. But in view of the enormity of capacity gaps in areas of integrated water resources management already alluded to, in-depth education and training is definitely required at the undergraduate level.

The School of Environmental Sciences in one South African institution -- the University of Venda -- is dedicated to filling that gap. At both the undergraduate and postgraduate levels, School programmes are designed to inculcate a high professional sense of sensitivity to sustainability through a focus on integrated resource management, sustained by the adoption of inter-disciplinary learning. Programme delivery aims to ensure an understanding and application of the strategies (and policies) for restoring, enhancing and maintaining resources in such a quality and quantity that will enable them remain beneficial to the present and future generations. Four-year (honours) degree programmes are offered with ultimate specializations in the following five Departments:

- Ecology and Resource Management;
- Geography;
- Mining and Environmental Geology;
- Urban and Regional Planning; and
- Hydrology and Water Resources.

A specific Department of Hydrology and Water Resources has been created from an old programme in Earth Sciences, to focus on training in many important areas of integrated water resources management. The central objective of the Department is to produce water professionals with a sound understanding of the usually missing elements for advancing the sector's business in the 21st century, including the ecological, planning, social and human perspectives. School graduates with a major in Hydrology and Water Resources are then able to work as team-playing professionals in industry, the public service and academic institutions, or as self-employed professionals.

The material covered in the 4th year includes project work and mini-dissertation, aside from advanced and applied treatment of important topics in the areas of focus. Further training beyond the honours level is being designed to allow for the pursuit of specialization in aspects of surface-water hydrology, groundwater hydrology, meteorology, water supply and sanitation, and water resources management. In pursuit of the Department's objective, the core curriculum of the undergraduate modular programme (Table 1) is packaged to provide an intensely relevant, non-conventional grounding in wide-ranging subject areas encapsulated in semester-long modules, in addition to an uncommon mix of School-wide modules. Whilst introducing students to important subject areas that directly address pressing national and community needs, sufficient material is retained in modules targeting a thorough comprehension of the principles (and practice) of hydrology, hydrogeology, meteorology, water supply and sanitation, and the quality and management of water as a resource.

In the very near future, the University will introduce a programme of staggered modules targeting water resource practitioners who need to upgrade their knowledge in aspects of integrated resource management. It is intended that the successful completion of six modules mounted for between one and two weeks will lead to the award of a Diploma in Water Resources. It is planned to discuss these modules, as well as others for converting to a master's degree programme, with key stakeholders in the water sector, including the Department of Water Affairs and Forestry.

Table 1: Core Modules in Hydrology and Water Resources

	FIRST SEMESTER	SECOND SEMESTER
YEAR ONE	HWR 1541: Introductory Hydrology & Meteorology HWR 1542: Introduction to Groundwater	HWR 1641: Southern African Weather & Water Resources HWR 1642: Water Quality Principles
YEAR TWO	HWR 2541: Rural Water Supply & Sanitation HWR 2542: Data Information Systems	HWR 2641: Water Law & Institutions HWR 2642: Drought Preparedness & Management
YEAR THREE	HWR 3541: Hydrologic Measurements HWR 3542: Atmospheric Dynamics HWR 3543: Fluid Mechanics	HWR 3641: Hydrologic Analysis HWR 3642: Hydrogeology HWR 3643: Water Quality Management
YEAR FOUR	HWR 4541: Applied Hydrology HWR 4542: Applied Hydrogeology HWR 4543: Water Supply Systems HWR 4999: Research Techniques & Project	HWR 4641: Water Resources Management HWR 4642: Applied Meteorology HWR 4643: Water Treatment Processes

CONCLUSIONS

Across all sectors, education and training are critical for promoting sustainable development and, in particular, for enhancing the capacity of people to effectively participate in decision-making processes that seek to address their sustainable development concerns and aspirations. Meeting the capacity building challenges of integrated water resources management in South Africa requires that local education and training institutions produce skilled professionals with a sound understanding of integrated management for sustainable development, amongst them a critical mass of blacks previously excluded by deliberate apartheid policies.

As part of its contribution, the University of Venda has developed (and is still developing) programmes to meet the needs of the sector. But certainly, in view of possible gaps in the actual delivery of programmes with varying elements of integrated management, avenues exist for education and training institutions in South Africa (and Southern Africa) to identify and consolidate their areas of greatest strength. This move should then set the basis for effective collaboration in capacity building in the water sector.

It should be pointed out though that, considering the practical nature of integrated water resources management, education and training facilitators in tertiary institutions need to have their own capacity built for effectively and efficiently transferring up-to-date knowledge, especially through continuous exposure to practice. Also, as institutions strategize to fill the demand for professionals in the vast inter-disciplinary area of integrated water resources management, there is need to note that a significant problem exists in attracting high numbers of high school graduates to this field, partly due to limited exposure to the subject matter. This concern is underscored in previously (and currently) disadvantaged communities where pre-tertiary academic preparation remains weak and the funds for surviving a four-year degree programme are difficult to raise.

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Water supply human resource challenges in Swaziland

Ola BUSARI

Dept. of Hydrology & Water Resources
University of Venda, Thohoyandou 0950, South Africa

busari@univen.ac.za

ABSTRACT

Several water sector training programmes have been initiated and successfully implemented in sub-Saharan Africa, but often with predominant assistance from external agencies. In a number of cases, including Swaziland, the weight of project-specific support imposed a project-oriented perspective of human resource development. Thus, to a large extent, the influence of that factor on organizational mandate and mission, as well as on the strategies used to pursue the mandate, dictated the sector's approach to human resource issues and human resource development practices.

Following the Government of Swaziland's increasing acceptance of the de facto obligation of providing (in addition to facilitating the provision of) safe water and sanitation to rural populations, a human resource development assessment has been accomplished. The key recommendations include the need to decentralize responsibility and authority to regional offices to enable them to deliver the complete range of rural water supply services; strengthen regional capacity to adequately liaise with communities and NGOs working with them; and widen the opportunities for engineers' career development and promotion.

Keywords: *water supply; rural; human resources development; institutional development*

INTRODUCTION

The low water supply and sanitation coverage levels in Swaziland's rural areas can be explained, in part, by the fact that the sector had hitherto depended heavily on donor resources. External assistance from multilateral and bilateral aid agencies played a major role in direct service delivery, institutional strengthening and human resource capacity building, with support from the Government of Swaziland coming largely in the form of recurrent funding (Busari, Dlamini and Mayisela, 1996). As of December 1995, a total of US$ 18 million had been spent on rural water supply and sanitation interventions (Busari, Mabuza and Okorie). Of that amount, 61% came from external support agencies; 39% from Government; and the rest from local civil society outfits. The investments resulted in the expansion of public access to potable water from 9% in 1979, 40% in 1986 and 42% in 1991, to 46% in 1996; sanitation coverage also rose from 19% in 1979, 25% in 1986 and 28% in 1991, to 36% in 1996 (Busari, 1996).

Much of the progress made in the rural water supply sub-sector resulted from the channelling of project funds through an agency established by the Government of Swaziland in 1976: the Rural Water Supply Branch (RWSB). But from its creation to signal Government's concern to improve rural access to water supply and sanitation, up until 1995, the RWSB never really existed in strict, legal terms: It operated as a continuous "temporary project" in accordance with the handouts and whims of donors. This unending temporary status meant that there was never any practical basis for projecting human resource needs and/or establishing training requirements. During the second half of the nineties, however, the RWSB received formal government "recognition" and was vested with the authority and responsibility for planning and guiding development within the rural water supply sub-sector.

In tune with ongoing initiatives to empower the RWSB to effectively execute its new mandate, this paper discusses the major issues, concerns and recommendations arising from a human resources development (HRD) assessment undertaken for the Branch. The paper, just as the HRD assessment process itself, recognizes that issues arising herefrom are only part of a larger human resources setting: both of the mother water (and sanitation) sector and, more importantly, of cross-cutting sectors at the national and regional levels.

ORGANIZATIONAL ROLE AND STRUCTURE

In taking up its role as the key government agency responsible for the provision of safe drinking water supplies to rural residents, the RWSB undertakes the following services:

- design and construction of water supply schemes;
- scheme maintenance, repair and, as may be needed, rehabilitation; and
- provision of policy, regulatory and technical advice on the design, construction and maintenance of water schemes, to other government departments, non-governmental organisations and rural communities.

To carry out these functions, the Branch was organized into six major sections as follows:

- Office of the Senior Water Engineer;
- Planning and Construction, including the four programme implementation units located in the country's administrative regions;
- Engineering Design;
- Public Health;
- Community Development; and
- Finance and Accounts.

The Senior Engineer provides overall leadership in the Branch, and is responsible for strategic management and administration. The Planning and Construction Section, manned primarily by one engineer, takes responsibility for developing the plans of operation for the Branch, in line with requests for water supply schemes from communities. Also, this section is ultimately responsible for construction supervision through regional units headed by Clerks of Works. Actual construction of water supply facilities is directly carried out by units located in the four administrative regions of Hhohho, Manzini, Shiselweni and Lubombo. Each regional office is normally the first point of call for communities who would like to improve their water supply. The application is first considered at this level, and an Assistant Community Development Officer works with and motivates the community to fulfill the requirements laid down for eligibility for intervention.

The Design Section is led by a civil/water engineer and takes charge of engineering design and draughting and, by extension, the development and enforcement of national design standards for all rural water supply schemes. This responsibility goes beyond schemes that are constructed by the RWSB, as it includes schemes proposed or undertaken by other development agents, including NGOs and private outfits. The Public Health Section – to which belong a sanitary engineer and (seconded) health inspector – ensures that the water supplied from all schemes is safe and continues to adhere to World Health Organization guidelines. The section also works closely with the Ministry of Health in encouraging communities to build latrines for the sanitary disposal of wastes.

The Community Development Section liases with rural communities for the vital purpose of mobilizing and sensitizing them to work proactively with the Branch, in order to sustainably develop, install, operate and maintain their water supply schemes. The section is headed by a community development officer, with district-level liaison provided by one assistant in each region. The liaison is triggered first by a request from a particular community for water supply (and sanitation) intervention. The approach of the RWSB is to respond to such requests in a manner that prepares and motivates the community to meet the basic requirements for putting up and operating a water supply scheme. The requirements, in no particular order, include:

- community education, understanding and acceptance of safe drinking water and sanitary practices;
- community consensus on the need (and implications) for a water supply scheme at a particular level of service;
- democratic formation of an inclusive community water and sanitation committee;
- community contribution to, and establishment of, a water and sanitation fund to cover the cost of scheme operation and maintenance;
- willingness of community members to contribute labour or cash or both towards scheme construction; and
- coverage of sanitation facilities in the form of pit latrines, to a minimum of 60% of the homesteads in the community.

KEY HUMAN RESOURCES ISSUES

The outlined organization of the RWSB was inherited from the period when rural water supply was treated as a temporary function. For two decades, sub-sector goals and objectives were stated only in very general terms and in a manner which lacked national commitment and consensus on the magnitude of what needed to be achieved and by when. In line with the short-term nature of specific projects and the funding donor requirements, the RWSB was organized to be reactive rather than proactive in its approach to the perceived sector needs and coverage expansion. In spite of policy shortcomings, however, the sub-sector recorded positive achievements especially in the sheer expansion of supplies to unserved communities. With the policy shift of 1995 towards a permanent institutional framework, the sub-sector needs to be more strategic in its pursuit of the national goal articulated in 1996, “to achieve full coverage by year 2020”.

Within the human resources context of that strategy, the main questions that surge to the fore are (i) what critical sections and units of the organisation need to be strengthened; and (ii) how can key staff be managed and motivated to work hard towards achieving the planned outputs. An examination of these concerns reveals the following major institutional constraints (Government of Swaziland, 1997):

- structural and human resource weaknesses in the regional units and the community development section; and

- limited opportunities for career advancement and promotion of a critical staff category, namely civil and water engineers.

First, there is a need to elevate the regional units to become genuinely decentralised offices of the RWSB, for the purpose of directly delivering rural water supply services and rapidly achieving planned outputs. This move requires that appropriate decision-making responsibility and authority, with the requisite resources and accountability, be devolved to this level. Under this arrangement, the head of the regional office -- the Clerk of Works -- effectively represents the Branch within his region of operation. The “new” regional offices should be re-organised in a way that enables them to deliver the complete range of services required for rural water supply, including full community interfacing and support, preliminary system design and construction, and major maintenance and rehabilitation backstopping as may be required.

Second, each regional office needs to be strengthened in terms of the capacity for community development work, in order to enable the RWSB to become more proactive in its widening interventions. The Community Development Section and its regional staff carry a very heavy work-load which is key to the success of improved rural water supply partnerships with communities. But the section is even more critical with regard to increased efforts to institutionalize community-level operation, maintenance and management of water supply schemes. The section suffers from a limited number of staff at the field level. Another concern is with regard to the adequacy of the training and skills of the current staff. Most staff members moved up from the artisan/technician cadre and possess very limited community development skills.

It is appropriate that the section be led at headquarters level by a new position of Senior Community Development Officer whilst, at regional office level, three new posts be introduced to bring the number of Community Development Officers to four. In this manner, all the current four Assistant Community Development Officers will remain in their posts. As much as possible in view of the financial implications, the four new posts to be created should be traded with existing posts, particularly within the category of vacant technician positions recently absorbed into the permanent establishment.

Third, the existing structure of the Branch is such that once an engineer came on board entering one of the three engineer positions -- Design Engineer, Public Health Engineer or Planning and Construction Engineer -- they got stuck there until either they were promoted to the only higher position of Senior Engineer or they simply left. Interestingly, a significant initiative was taken in a separate Ministry (of Works) in 1992, to introduce a scheme of service for engineering staff. The initiative established the following career ladder for all engineers:

(i) Assistant Engineer (graduate being trained to obtain professional qualifications);

(ii) Engineer (professionally qualified);

(iii) Senior Engineer;

(iv) Principal Engineer;

(v) Chief Engineer; and

(vi) Chief Professional Officer (at the level of Director of Works).

That the scheme of service was officially accepted for implementation by Government and is currently operational in a sister Ministry makes the situation at the RWSB obviously unattractive and demoralising. In order to institutionalize career development and promotion for engineers in the RWSB, it is considered urgently necessary that:

(a) the (grade 12) positions of Design Engineer and Public Health Engineer, whilst remaining as such in titles, be multi-graded for the purpose of career advancement based on performance, as grades 12, 13 and 14;

(b) the (grade 13) position of Planning and Construction Engineer, whilst remaining as such in title, be multi-graded to permit upward mobility based on merit, as grades 13, 14 and 15; this step practically transforms the post to the level of deputy head of department; and

(c) the (grade 14) post of Senior Water Engineer be upgraded to the level of Chief Water Engineer, and put on grade 16 as is applicable to other Heads of Department (Engineering) in the Ministry of Works.

In particular, the option of multiple grading affords an opportunity for career advancement within one post, without recourse to the more costly alternative of creating the additional posts of Senior and Principal Engineers.

CONCLUSIONS

External support to Swaziland's rural water supply sub-sector and staff development played an important role during the early phases of the development of the sub-sector. However, the nature of the support introduced and sustained a project-oriented view to human resources issues and human resource development practices in the Rural Water Supply Branch, the key institution responsible for ensuring adequate rural access to water supply. Following reductions in external support in the 1990s, the greatest challenge was how to deal with the large number of temporary project staff in the RWSB. Government reacted positively and flexibly to this challenge, even though forecasting the levels of human resources demand in the sub-sector was being attempted within the new framework of linking this demand to institutional performance targets.

The structural problems in the RWSB include very high workloads in the Community Development Section which has inadequate number (and qualification) of staff; and weak regional offices with limited authority and capacity to respond to the demands for service in their regions. There is need to effectively decentralise responsibility and authority to the regions. The new regional offices should be reorganized in a manner that enables them to deliver the complete range of services required for rural water supply, including full community interfacing and support, preliminary system design and construction, and major maintenance and rehabilitation backstopping as deemed necessary. In addition, the capacity of each regional office to meaningfully liase with communities should be strengthened with the introduction of an additional post of Community Development Officer, to be filled by individuals with training in sociological and/or anthropological issues.

From the perspective of human resources demand-supply imbalances, the most critical occupational category in the RWSB (and indeed, in the sector at large) is that of civil/water engineers, for which demand could easily exceed supply. Addressing career development and promotion is especially important for RWSB engineers. It is vital to link this urgent need to the approved engineering cadre in government service. Multiple grading of engineering posts is considered the most viable route for the RWSB, with the post of planning and construction engineer being upgraded to the level of deputy head of department.

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Water resources and water supply for rural communities in the Sand River Catchment, South Africa

John BUTTERWORTH[1] , Kogpotso MOGKOPE[2], and Sharon POLLARD[2]

[1]Natural Resources Institute (NRI), University of Greenwich, Chatham Maritime, Kent, ME4 4TB, UK
[2]Association for Water and Rural Development (AWARD), Acornhoek, South Africa

[1] j.a.butterworth@gre.ac.uk

ABSTRACT

The allocation of water to previously disadvantaged sectors is an important concern throughout South Africa. In drier areas where available water resources are heavily utilised, such as the Sand River Catchment, this represents an even greater challenge. This paper addresses how catchment management reforms are being implemented to improve the allocation of water resources in South Africa, using the Sand as a case study. It argues that as well as supporting emerging farmers to engage in small-scale irrigation, more emphasis needs to be given to the rural water supply sector and especially productive uses of domestic water at a household level (to support activities such as backyard irrigation, beer brewing, brick-making and construction). The paper considers: how the needs for water to support rural livelihoods can be articulated (to achieve policy changes) and supplies improved to promote productive water uses (given technical, economic, resource and other constraints); where additional water resources for productive water use at the household level (and small-scale irrigation) will come from; and, drawing upon experiences from the Water, Households and Rural Livelihoods (WHIRL) project (involving South Africa and Indian partners), how lessons can be learnt from some other countries (such as India) where water resources legislation and institutional reform have been largely unsuccessful to date.

Keywords: *rural water supply; integrated catchment management; integrated water resources management; participation*

1 INTRODUCTION

The water sector in South Africa is currently going through a period of major change and reform. This has profound implications for both water management and water services in rural and urban areas. The recent National Water Act (RSA, 1998) has established the basis for management of water resources on a catchment basis (for equity, efficiency and sustainability), and the Water Services Act (RSA, 1997) aims to ensure everybody has access to basic water supply and sanitation services.

Against this background, water use clearly needs to increase to meet people's needs and to help raise standards of living. More water is required not just to meet basic needs for drinking, washing, cooking and sanitation (an amount of 25 lpcd is recognised – the so-called 'RDP' minimum) but also to promote productive uses of water at the household level, and village-based enterprises including small-scale irrigation.

The contributions to rural incomes, food security and the wider economy from small-scale irrigation are widely acknowledged, but the contributions to livelihoods of water use for productive activities at the household level, and for normally 'informal' village-based enterprises are rarely considered. Productive water use at the household level includes activities such as backyard irrigation, beer brewing, dairying, brick-making and construction. These have been shown to have important economic, nutritional and other benefits (e.g. improved shelter) for poor communities in dryland areas (see Box 1). Other village-based enterprises include activities such as community gardens and raising poultry. These productive activities must be better recognised in order for rural water supply (RWS) to become more demand-responsive (Moriarty, 2001)

However, productive uses of water at the household level over and above basic needs are not explicitly recognised in policy. Since the National Water Act clearly recognizes water for the agricultural sector, a mechanism for improved allocation of water to emerging farmers exists. But other productive uses of water are largely invisible – the sector is largely informal, fragmented and lacks representation - and the false assumption is often made that domestic water is only required and used to meet domestic needs such as drinking water, washing and cooking. The Water Services Act also focuses on meeting basic needs for water supply. Until policy changes, water is unlikely to be allocated for such productive uses at the household level on a wide scale.

Box 1 Productive use of water

A study in the Bushbuckridge area, South Africa (Perez de Mendiguren, 2001) showed

- high-levels of water use for economic activities in villages, with both poor and good water supplies, ranging from 23 lpcd to 40 lpcd above the amount used for basic needs (21-22 lpcd).
- economic returns are relatively high, ranging from 0.01-0.02 R/l for vegetable gardens and fruit trees (the most common use of 'extra' water) to 1.2-1.6 R/l for beer brewing and ice block making. (1R=US$0.06)

The current changes and trends raise some interesting questions. How can the needs for water to support rural livelihoods be articulated (to achieve policy changes) and supplies improved to promote productive water uses (given technical, economic, resource and other constraints)? Where will additional water resources for productive water use at the household level (and small-scale irrigation) come from? And, how can experiences in some other countries (such as India) where rapid increases in groundwater use for small-scale irrigation have compromised domestic water availability, be avoided? (Butterworth *et al.*, 2001).

This paper explores these issues focusing on the allocation of water resources to the rural water supply sector and participation in these decisions. It focuses on the Sand River Catchment where a national pilot project for integrated catchment management (the Save-the-Sand project) is underway.

2 SAND RIVER CATCHMENT

In the Sand River Catchment most of the existing surface water resources are already utilised (Pollard *et al.*, 1999), and any increased use for previously marginalised sectors and communities will need to be met through: groundwater development; reduced use in other sectors or areas; or transfers from outside the catchment (construction of a new dam has made basin transfers possible). Competition for scarce water resources and inappropriateness of priorities in water use have been widely recognised since the 1992 drought. Tankers had to be used as an emergency water supply to rural communities and large numbers of wildlife and livestock died, while irrigated agriculture utilised water without restriction. This crisis acted as a catalyst and stimulus for an integrated approach to water resources management to be adopted.

The catchment (1910 km^2) is located in the north east of South Africa draining parts of Northern and Mpumalanga Provinces (Figure 1). It is part of the larger Sabie and in turn, Inkomati Catchments. Important land uses - roughly from the upper to the lower parts of the catchment - include plantation forestry, dryland and irrigated agriculture, relatively dense rural settlements (a legacy of the apartheid system), game reserves and the Kruger National Park towards the Mozambique border. It is a dry area, but water scarcity for the majority of the population has been exacerbated by the political and social engineering of the apartheid government. As a result, 44%

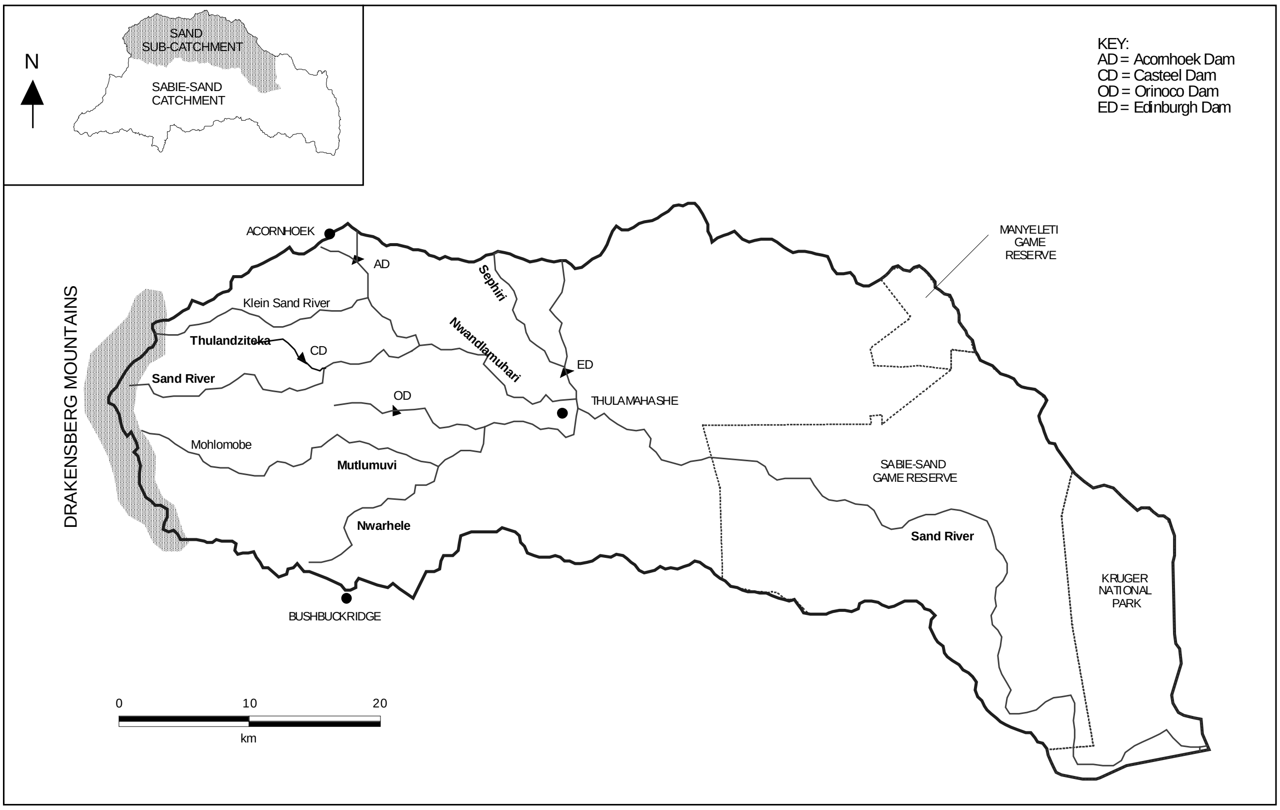

Figure 1. The Sand River catchment, indicating the catchment boundary, major rivers, existing dams and game reserve boundaries.

of the population were estimated to have supplies below government minimum levels (25 lpcd of potable water from a standpipe within 200 m of each household) (Pollard & Walker, 2000).

3 WATER RESOURCE ALLOCATION AND USE

Currently there are no active water allocation mechanisms in the Sand River Catchment. *De facto* 'allocation' is determined by current water use patterns (although water users had to register from mid-2000 in order to regularise existing use) that remain poorly understood. A moratorium is in place on any allocations to new users. The largest water user is the irrigation sector (estimated as 32.3 Mm^3 in 1985). This includes both irrigated plantations of citrus, coffee and mango, and small-scale irrigation (mainly field crops). Forestry (mainly exotic species such as pine) in the upper parts of the catchment is another large water user (11.3 Mm^3 in 1985). Domestic water use (to meet minimum needs only) in comparison is estimated to account for 3.5 Mm^3 (1998 estimate). However, when actual water use for basic needs and household productive uses are taken into account, the real water need from 'domestic' water supply systems may well be two to three times greater. Also, at a village scale domestic water needs can account for a large proportion of the yield from local aquifers, and during droughts needs may equate to a much larger share of the available resources than during normal years. Finally, the environment and river flows to Mozambique are also important components of the catchment water balance.

Some of the reasons why domestic water use represents only a small component of the overall water balance are: water resource constraints (e.g. upstream use impacting on downstream users); poorly planned infrastructure; and inadequate operation and maintenance. These factors result in actual domestic water use being much lower than need. However, this relatively small component of the water balance is obviously of vital importance.

In the Sand River Catchment, surface water resources are heavily utilised, but groundwater has not yet been fully developed. Historically, investment in rural water supplies has focused on extensive bulk water supply systems utilising surface water resources (relying upon large dams, treatment works and distribution networks). But in many cases, the planned reticulation systems have never been completed. Current RWS efforts, implemented by government and non-governmental organisations such as the Association for Water and Rural Development (AWARD), are more focused on local (i.e. single village or sub-village) groundwater-based schemes. Resource use for RWS is now perhaps evenly split between surface and groundwater.

Despite the vast improvements in water supply to the rural sector made by the South African government, many of the current patterns of water use are still characterised by inequality, inefficiency, and inadequacy. The poor remain marginalised, and emerging farmers and poor rural communities have limited access to water resources while water continues to be used inefficiently by an irrigation sector with few incentives to improve its water use efficiency.

Important changes are now made possible by the abolition of riparian rights, and the planned licensing of water users based upon criteria that promote equality, efficiency and sustainability (Box 2). One key new concept is the Reserve; a theoretical minimum quantity designed to ensure the availability of water for human needs and the environment. The implications for rural water supply are still emerging, and it remains unclear how the component for human needs will be operationalised and managed. For example, initial attempts in the Sand River Catchment simply estimated domestic water needs based on population, but improved approaches will need to account for losses in distribution, and carefully consider where and how the Reserve is made available. Theoretical availability of sufficient water at one point in the catchment (e.g. in a river) will have little relevance for water supply systems that are not connected to a reticulation system to transfer bulk water around the catchment, or for settlements dependent on a groundwater supply. In addition the new allocation process must address temporal issues such as droughts (a reserve should be utilised during droughts and re-established during wet periods), and the potential future development of groundwater for small-scale irrigation.

Box 2 Establishment of Catchment Management Agencies (CMAs)

The National Water Act has abolished riparian rights, established a Reserve for human needs and the environment, and recognised water as a social and economic good. CMAs are being formed to manage water resources based upon a catchment management strategy. One of the key tasks will be to allocate water to different users, and this is intended to be more equitable, efficient and sustainable than past patterns of use. They are intended to promote participation and be more demand responsive. A proposal for an Inkomati CMA (including the Sand), based upon an extensive consultation process has been completed (DWAF, 2000). However, it remains uncertain how quickly such structures will take to be established – perhaps as long as 7-15 years.

As explicitly recognised in current government policy, one important factor that will influence the future allocation of water for the rural water supply sector will be the participation of key stakeholders (e.g. local government and consumers, NGOs and other institutions that take responsibility for advocating the rights of the poor and marginalised) in the emerging catchment management fora.

4 PARTICIPATION IN WATER RESOURCE ALLOCATION

While the RWS sector has been actively promoting community participation in the management of rural water supply systems, improving participation in water resources management (which has to happen at a larger catchment scale) is a relatively new challenge for the sector. Recent efforts have actively promoted participation of the RWS sector in catchment management and used these lessons to develop guidelines (DWAF, undated; DWAF, 2001).

There are likely to be important differences between avenues for representation of the interests of the RWS sector, dependent upon on the type and scale of water supply systems. Smaller-scale systems (usually groundwater-based and serving part, one or a small number of villages) will be represented through local government as a Water Services Provider. The water resource needs of consumers served by multi-village bulk water supply schemes (surface water) can also be expected to be represented by water boards (e.g. the Bushbuckridge Water Board in the Sand River Catchment) with collective muscle. Most attention is currently focused on these latter systems (i.e. surface water), although groundwater-based systems may supply just as much water.

Some emerging lessons from the Save-the-Sand Project (that includes community water supply and improved allocation of water at a catchment scale amongst other activities) on achieving participation include:

- the high-costs of participation;
- difficulties in working closely with local government (i.e. lack of capacity) where personnel (and in the current period, roles and responsibilities) change frequently;
- the need to recognise fragmented or marginalised stakeholders and uses that can be too easily overlooked – for example, productive water uses of domestic water has up to now been a largely invisible sector; and,
- the requirement for a good and even knowledge base for all stakeholders to participate effectively. 'Platforms' need to be created where very different stakeholders can communicate effectively.

5 THE WATER RESOURCE FUTURE FOR RURAL WATER SUPPLY

On paper, the water resource future for the basic needs element of rural water supply in the Sand River Catchment and elsewhere in South Africa is secure. Strong legislation, incorporating innovative elements such as a Reserve that provides for human needs and the environment, and plans for better institutions and structures are now in place.

However, a number of caveats must be made:

- experiences elsewhere (e.g. groundwater legislation in India) have shown that legislation can be ineffective and hard to implement,
- regulatory approaches to water resource allocation will require high levels of capacity in the catchment management bodies,
- corruption has proved a major weakness to such approaches in other countries, and
- institutional inertia and capacity limitations (especially at local levels) are also major constraints. In this respect, NGOs and NGO associations could play a stronger role in the implementation of the new policies.

Importantly, whether more water will be available for productive uses within the household and for village-based enterprises is uncertain and remains to be addressed. The RWS sector must engage with these issues to ensure that water allocations for productive uses (over and above basic needs) can be realised, and that basic needs are protected (at the lowest possible cost) in practice as well as in principle.

Box 3 Water, Households and Rural Livelihoods (WHIRL) project

AWARD is currently undertaking research in the Sand River Catchment on the key issues raised in this paper: the use of rural water supplies for productive uses, and how water resources for the RWS sector will be protected by new water resources management policies, legislation and regulation. This work is being carried out as part of the WHIRL project involving partners from South Africa, India and the UK. Further details about the project can be found at http://www.nri.org/WSS-IWRM/

6 ACKNOWLEDGEMENTS

The WHIRL project (Box 3) is supported by the UK Department for International Development (DFID) through the Infrastructure and Urban Development Division's Knowledge and Research programme. Project R7804 'Integrating drinking water needs in watershed projects'. Comments on a draft of this paper by Patrick Moriarty and Charles Batchelor are acknowledged.

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Remote sensing CCD rainfall estimation in Zimbabwe.

Eng KY. BWANALI

Agri-Support Network (SADC Region), PO BOX BW1619, Borrowdale, Zimbabwe

turnkey_project @hotmail.com

ABSTRACT

Hydrological information is of vital importance to sustainable development. Rural and remote areas, now faced with serious pressure to develop, lack information on not only rainfall but also river flow and evaporation. Rainfall is the dominant forcing factor for most hydrological processes. Rainfall may be estimated for ungauged areas using Cold Cloud Duration (CCD) Technology. CCD estimates are based on the cloud top temperature. Rainfall formation is related to the cloud top temperature and the duration during which the temperature of the cloud was below a threshold level.

International watersheds in the region are usually characterized by ungauged and partially gauged areas. With rainfall estimates and other relevant considerations, it is possible to estimate the effective contribution (in IWRM context) each subcatchment has to the shared watercourse. Currently a lot of effort has been put into the development and use of CCD technology in rainfall estimation internationally. The methodology and technology is still not developed to the level necessary for simple and general use by potential beneficiaries.

The development of CCD rainfall estimation tools, in essence, is not a duplication of rainfall records but a vital input into the augmentation of the national rainfall records. The particular applications of the methodology that would be of benefit to the users of rainfall and hydrological information are:

a. *The estimation of rainfall at other points other than those currently gauged.*

b. *The estimation of rainfall over large areas where point rainfall records would be difficult to apply with acceptable accuracy.*

There are problems related to point rainfall measurement and their subsequent use in the estimation of areal rainfall in large catchments. Indeed, the most widespread application of point rainfall records is in the estimation of rainfall in relatively large areas, typically over 100 km^2. The gauging stations are frequently sparsely located. Point rainfall gauging networks are reducing in capacity with most used facilities in need of repair and maintenance. CCD rainfall estimation has the advantage of being inherently spatial. Most areal rainfall assessment methodologies use networks of point gauge measurements.

In Zimbabwe a methodology has been developed to relate CCD and rainfall. This method uses a regional approach in which regions of homogenous rainfall are related to CCD using linear relations. Applications of these relations would be on "near real time". When functional these systems would assist in flood focusing and rainfall estimation over large partly gauged catchments. The method has algorithms that optimize on CCD threshold temperature, cloud temperature, season establishment, rainfall type and ground data coverage. Spatial variability of rainfall is important to most development oriented data requirements. This is for variation in both space and time. Averaging of rainfall from sparsely spaced rain gauges may be misleading in highly variable local rainfall coverage. Information on rainfall may be translated to crop productivity information, run off or similar.

Keywords: *data; rainfall; cold Cloud Duration (CCD); Remote Sensing; Hydrology; Modeling; Areal; Pixel; Dekad; Homogenous Regions; calibration; Kriging; variance; digital Terrain Model. (DTM); Runoff; Cloud Top Temperature; Gauging Stations; Threshold Temperature; Spatial Variability; IWRM; Geostatistical; TIR Images*

1. INTRODUCTION

When one talks about regional rainfall relations, one should understand that the fundamental component is “areal” meaning application over large areas. The development of regional CCD – Rainfall estimation relations is driven by the ability of one to estimate accurately rainfall over large areas. Satellite derived CCD estimation fields are inherently “areal”. The other critical input into the process of rainfall estimation is ground rainfall. All our ground rainfall records are for point rainfall gauges. A rainfall field that is “areal” is hence important if any CCD – Rainfall comparison is to be made.

As with any geographical region, the SADC sub region is controlled by dominant weather systems that tend to be localized. Time aggregated rainfall records over long periods confirm these systems. Besides dominant weather systems, local geographic areas are also strongly influenced by locality, aspect, topography, soils, land cover and management. In adopting a regional approach, homogenous rainfall regions are identified. These regions are those areas where rainfall systems are strongly correlated. The influence of these rainfall systems with time and geographic locality (temporal and spatial correlation) also influences geographical or spatial distribution by time of correlation parameters. It was generally observed that areal rainfall fields in most regions influenced by frontal and convective rainfall systems have anisotropic relations.

This implies that for most rainfall regions in Zimbabwe the ***range*** of influence is longer along the rainfall fronts (west to east) more than that across the fronts (north to south). The guti type rainfall providing a different geostatistical distribution and correlation influences some regions. Current tools used in CCD based rainfall estimation for the region have approaches that simplify Zimbabwe into one region with other neighboring countries. This has been behind poor estimations in some regions of the country due to localized climatic systems. It is the original aim of the project to improve on these limitations currently experienced.

2. BASELINE STUDIES

Rainfall Data

While it is appreciated that data may be classified as primary, secondary and tertiary, it can be justified that rainfall data is fundamental primary data required for development (Clarke, 1973; Doorenbos and Pruitt, 1977). Rainfall is a forcing function in hydrological processes (Schulze, 1995).

Application of rainfall and other types of data is always for areas larger than the point kept on record. Such application areas range from 10km^2 to over 4000km^2 (Hughes, 1997). Secondary data including runoff modelling and flood focusing.may be derived from rainfall with consideration of the hydrological physical site description (Schulze, 1995; Hughes, 1997; Jain et. al., 1997; Verdin, 2000; Adegu, 2000). Other aspects like evaporation are also driven by rainfall.

Remote Sensing Potential

TIR images are inherently used to infer temperature showing both temporal and spatial variation (Allan, 1984; Allan, 1990; NASA, 1987). The health status of vegetation may be interpreted from a combination of individual frequency bands (CIESIN, 1992; Lillesand and Kiefer, 1987). The near TIR (5.7-7.1um) give details on atmospheric water vapour while the TIR range (10.5 – 12.5um) can be used to identify thermal phenomena including cloud top temperatures and cloud height estimation. (Lillesand and Kiefer, 1987).

The temperature of cloud tops had been related to the potential of rainfall formation (Grimes and Bonifacio, 1999; Pingping, 2000). The duration that the cloud top temperatures were below the threshold temperature for rainfall formation is also related to the amount of rainfall (Grimes and Bonifacio, 1999). Precise relationships depend on several factors including rainfall type, cloud type, image resolution, prevailing atmospheric conditions, season etc (Gimes and Bonifacio, 1999; Pingping, 2000; Bwanali, 2000).

Remote sensing technology may be used successfully in providing alternative rainfall data or other useful data if the following principles are considered.

a. Homogeneity/variation of systems and extent of influence.

b. Clarified relationship with observed parameters (time and space sensitive).

c. Regionalise and qualify relationships.

Rainfall Estimation

Several methods have been developed for use in Satellite derived rainfall estimation. These include the Reading TAMSAT Method that uses historical raingauge data networks and satellite derived CCD units calibrated from the same region and time of the year. Rainfall is estimated using calibration coefficients (Grimes and Bonifacio, 1999). Rainfall estimates are merged with a spatial rainfall field generated from raingauges using weights inversely related to the variance. The rainfall field generated is to the same spatial; and aerial resolution as CCD images using Kriging geostatistical methods (Grimes and Bonifacio, 1999).

Rainfall is assumed to be predominantly convective in origin and that the threshold temperature for raining clouds is correctly set for minimum detection errors (Grimes and Bonifacio, 1999). The Cold Cloud Duration is assumed to be linearly related to the rainfall amount.

The CPC RFE method developed by the Climate Prediction Center of National Oceanic and Atmospheric Administration (NOAA) uses real-time gauge observations, satellite estimates and numerical model prediction (Pingping, 2001; Allan, 1990; Verdin, 2000). Five basic inputs used in model are from GTS gauge observations and estimates from multiple satellites. Topographical effects are not included in the model (Pingping, 2001). The five inputs required are:

- GTS gauge observations of daily rainfall
- GPI rainfall estimates from METEOSAT IR observation
- Rainfall estimates from SSM/I microwave observation
- Rainfall estimates from AMSU microwave observation
- Rainfall field from NOAA/NCEP/GDAS numerical model

Rainfall estimation algorithm combine these images through a merging procedure that attempts to account for GTS ground observation, GPI cloud temperature and height, SSM/I and AMSU particle ice and large water droplets and the Global Data Assimilation System (GDAS) numerical model.

Other methods like the EARS method use several temperature thresholds to optimize on detection errors.

4. AIM OF THE PROJECT

The general objective is to develop tools for use in estimating rainfall from CCD units for regions in Zimbabwe using improved methods. These regional relations may be used to estimate rainfall when areal rainfall estimates are required or when no ground point rainfall measurement facilities are available.

5. METHODOLOGY

Brief on CCD Production

TIR Images from the geo-stationary satellites as Meteosat have high temporal resolution of about 30 minutes with a spatial resolution of a few kilometers. From these TIR images rainfall can be deduced. TIR images give a measure of cloud top temperature that can be used to identify convective storms and imply a rainfall rate. TIR images with temperature records on a spatial grid (pixels) are passed through a threshold temperature test. If a pixel records a temperature below the threshold temperature, a pixel is recorded as having registered a single CCD unit. Each 30–minute image is processed the same.

After a day several 30-minute CCD images based on the threshold temperature are added up to produce the total number of CCD units recorded on each pixel. This image becomes the cumulative daily CCD record. Ten daily images are usually added together to produce the dekad CCD unit images. These images are useful for agricultural focusing purposes. There are problems, however, relating to the use of TIR imagery in estimating rainfall. This is because none of the sensors on the satellite measure rainfall perse. TIR images need to be calibrated with rainfall recorded on the ground. Calibration coefficients vary spatially and temporally

The Rainfall Estimation Method

The method uses both raingauge networks and satellite derived multi-temperature threshold CCD units. Rainfall estimates from calibration in homogenous regions are then merged with a spatial rainfall field generated from raingauges to the same aerial or spatial resolution as the CCD image pixels. The merging is carried out by calculating a weighted average of the satellite and raingauge estimates for each pixel with weights that are inversely related to the variance on the individual estimates.

With this method the rainfall estimates are made from geostatistical methods using gauge data with the same spatial frame of reference as the satellite estimates.

Assumptions of the Method

The method uses cloud top temperatures calculated from Meteosat TIR images.

Rainfalls for 10–day periods (dekads) are calculated on the basis of the following assumptions:

1. Rainfall is predominantly convective in origin. Raining clouds can be identified as those with a temperature below a threshold temperature (T).
2. The number of hours for which a given pixel is colder than T (the Cold Cloud Duration or CCD) is linearly related to the rainfall over the same time period.

3. The threshold temperature T and the parameters a_0 and a_1 can be estimated for a given region and a given time of year by analysis of data for that region and time of year.

The calibration zones are defined to be homogenous rainfall areas with sufficient raingauges to give statistically reliable calibration. Rainfall in most of Zimbabwe is influenced by the passage of the Inter-Tropical Convergence Zone (ITCZ) with the exception of the highlands where orographic rainfall is witnessed and the southern part with the guti type rainfall. There is significant inter-annual and spatial variability in rainfall – CCD relationships as a result. This can lead to over or under estimation if fixed calibration coefficients are used for a particular month and locality.

To select the optimal threshold temperature, comparison of detection errors is useful. The use of multi-threshold temperature images adapts the analysis to the best threshold temperature for the region by according appropriate weights.

Success in rainfall detection is when **CCD = 0 and R = 0; CCD > 0 and R > 0. Otherwise t**he threshold temperature is too cold when **CCD = 0 when R > 0** (No detection error) or too warm when **CCD > 0 when R = 0** (False detection error). For a given zone, the threshold temperature is defined as that which gives the best agreement between gauges and the corresponding satellite pixels as to the presence or absence of rain.

Details of the Calibration Procedure

The calibration parameters are determined by regression between the kriged pixel rainfall estimates from the raingauge data against the CCD values for the pixels containing gauges. The **Median and mean regression method was used.** The regression is made between the median rain in each CCD class and the mean CCD class. A weight related to the number of data points in each CCD class is estimated. Data with zero CCD is excluded from the regression. This assumption eliminates "No Detection" Errors. This result in weighted regression.

Areal Rainfall Estimation From Raingauge Data

There is difficulty in comparing data from gauges with those from satellites in that they provide two different kinds of information. Satellite estimates are essentially averages over the area of the satellite pixel, while gauges provide measurement made at a point.

A standard geostatistical procedure for merging the spartial information provided by the CCD image and raingauges data is known as Kriging with external drift (KED). KED is generally used to merge two sources of information; a primary gauge rainfall variable that is precise but only known at few locations and a secondary CCD record variable everywhere in the spatial domain. The second variable is related statistically to the primary variable.

Merging of Gauge and Satellite Data

A weighted average rainfall value is calculated for each pixel with the weights proportional to the inverse of their estimation variance.

While the kriging estimation method generates estimation variance, additional variance need to be calculated from the regression of the CCD values and kriging pixel rainfall estimates. This is achieved by assuming that the total variance (or regression variance) of the satellite pixel estimates against the kriged pixel estimates is due to the combined effect of the kriging variance and the satellite variance. The two errors are independent.

The total regression variance is not constant (heterocedasticity). The changes in the total regression variances depend on the rainfall amount. This dependency may be obtained from experimental historical data. A non-parametric procedure of estimation consists of using the absolute value of the regression residuals as proxies of the standard error.

This procedure works well for high rainfall amounts. For low rainfall amounts, a combination of a small regression variance and a relatively large errors that may lead to unrealistic estimation confidence. To avoid this the value of variance is established by considering that the satellite estimation variance can be further broken down into two components.

1. **Collocation variance that** represents the uncertainty with which the CCD is known for a given pixel. This is due to both the limited accuracy with which the geographic location of any pixel is known and the leakage of radiance between pixels.

2. **Distribution Variance that** is the uncertainty involved in using the true CCD as an estimate of rainfall and reflects the stochastic nature of the relationship between CCD and the rainfall quantity.

These errors are also independent.

6. RESULTS AND DISCUSSION

Attempts to improve on the coverage and sensitivity of the identification of regions from ground rainfall records and from CCD satellite images as through improvement of Principal Component Method (PCA) sensitivity and improvement of ground rainfall record coverage to include 130 stations locally and over 25 stations from stations in neighbouring countries. The final process involved the consolidation of rainfall regions as identified by ground rainfall records with rainfall regions identified using CCD satellite technology

The result has been the delineation of homogenous regions with a tight correlation coefficient and covariance cut-off limit. This was done for the months of October, November, December, January, February, March, October to December and January to March.

Figures 1 and 2 were obtained from using a single threshold temperature of –40 degrees Celsius. Significant detection errors have been observed during the establishment and decay of the rainfall system. Figure 2 show a comparison between dekad CCD rainfall estimation and areal rainfall estimates in a partially gauged catchment.

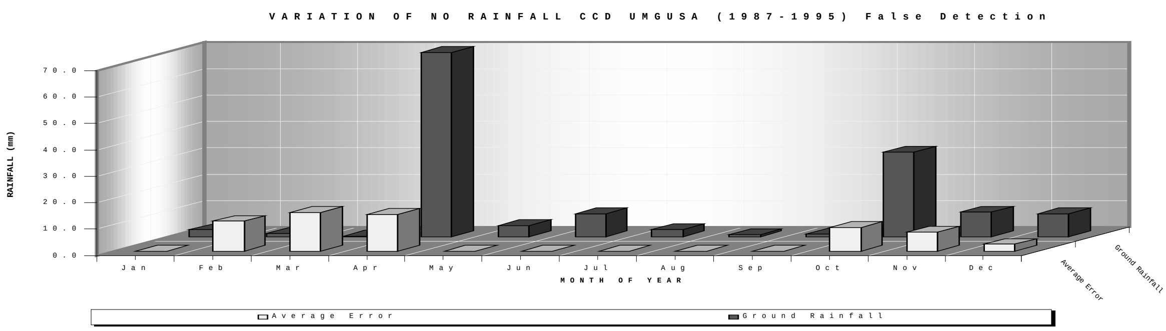

Figure 1: No Detection and False Detection Errors

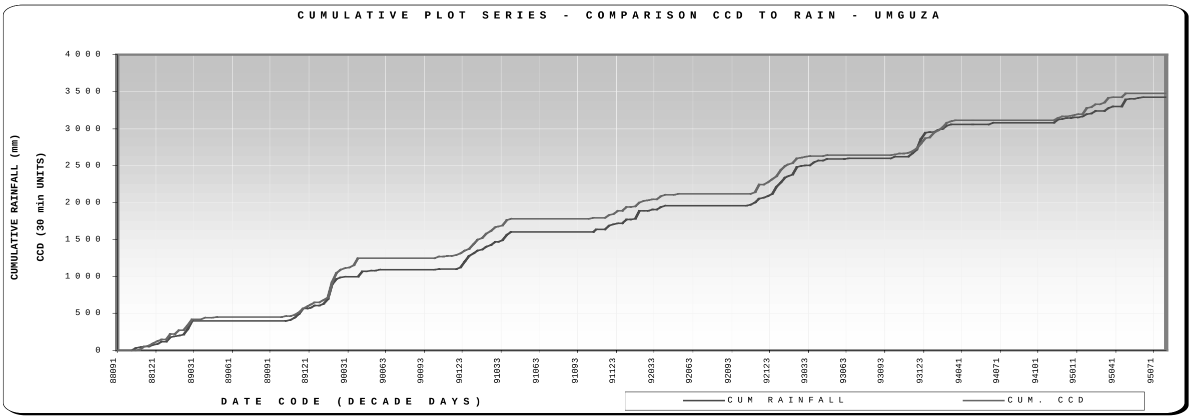

Figure 2: Comparison of Areal Dekad CCD Rainfall Estimation

Sources of observed errors include incorrect threshold temperature (detection errors), point rainfall not representative of areal rainfall, locality of recording station relative to pixel center, spatial resolution of image relative to rainfall spatial variability, type of rainfall, aggregation of data, prevailing conditions and deficiencies in point rainfall records.

Figure 3 below show an example of homogenous rainfall regions delineated by the CPA method for both raingauge records and satellite derived CCD units for the period January to March.

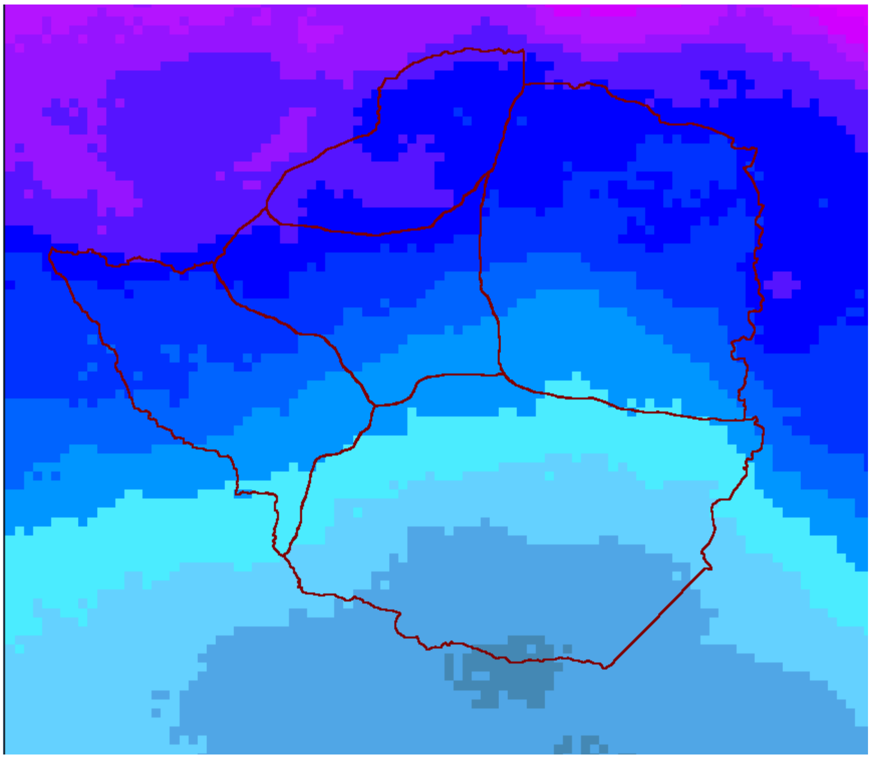

Figure 3: JFM Period Homogenous Rainfall CCD Regions

7. CONCLUSIONS

The use of multi-threshold temperatures reduces detection errors. CCD-Rainfall relationships are strongly influenced by the geographic location and rainfall systems of the area under investigation. Besides rainfall estimation, remote sensing may also be used for water resources assessment in wetlands (Lillesand and Kiefer, 1987), hydrology (Allan, 1990; Verdin, 2000), soils and vegetation assessment and mapping (Allan, 1990), crop yields focusing (Mellart, 2000), soil moisture indexing (Mellart, 2000), temperature (Lillesand and Kiefer, 1987) and evaporation (CIESIN, 1992)

With good spatial and temporal data availability, it is possible to establish primary and secondary remote sensed data and ground truths for generating data in areas with poor coverage. Besides, areal data is more representative and more appropriate for use over large areas when compared with point records. The potential for applying remote sensing in accurate areal rainfall estimation is great. Accurate estimation algorithms are those that focus on localized relationships that acknowledge local influences and systems

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Pollution implications of disposing wastewater in pasture lands

M.J. CHIMBARI[1], S. MADYIWA, R. MUSESENGWA, S. MUKARATIRWA and J. NYAMANGARA

[1] ulkrs@telco.co.zw

ABSTRACT

Disposal of sewage sludge on land may be both beneficial and detrimental to the environment. Sewage sludge contains valuable plant nutrients and organic matter that can improve soil fertility and structure. However, it also contains pathogenic bacteria, viruses and protozoa along with potentially toxic elements, all of which give rise to potential hazards to the health of plants and animals including human beings. This study is investigating possible accumulation of potentially toxic metals, mainly Cd and Pb in sandy soil and pasture grass irrigated with effluent and sludge at Firl Farm in Harare. Furthermore, the study is investigating the implications of the wastewater irrigation practice on health of cattle raised on the pastures and on the quality of beef produced. Results obtained to date show high levels of Zn, Cu, Cr and Pb in the top 20cm, particularly the top 10cm of the irrigated soils and comparatively low levels of metals in soil samples collected from all soil profiles of the control area. Chemical analysis of samples collected from the irrigated pastures have shown levels of 341.5g/kg, 63.5mg/kg and 3mg/kg for Zn, Cu and Pb respectively. Analysis of wastewater from the point of entry to the treatment works and effluent samples at the point of irrigation indicate that most parasites that reach the plant survive the treatment process. The parasites include: Ascris lumbricoides, Giardia lamblia, E.coli, Cyclospora spp and Schistosoma mansoni. Strongyloides spp and coccidae spp were found in faecal samples of cattle restricted to the wastewater irrigated pasturelands, thus indicating active transmission of the parasites. These preliminary results indicate that use of wastewater could have far reaching implications. Assessment of quality of beef and groundwater is in progress.

Assessment of the environmental impact of squatters on surface water sources in Malawi: Case study of Luchenza River in Blantyre, Malawi

Victor CHIPOFYA

Department of Civil Engineering, University of Malawi – The Polytechnic, P/Bag 303, Blantrye 3, Malawi

vchipofya@poly.sndp.org.mw

ABSTRACT

An assessment of the physical, chemical and microbiological quality of the Luchenza River, adjacent to Mtopwa squatter area near Bangwe Township in Blantyre, Malawi was undertaken to determine the suitability of the water for domestic purposes (drinking, bathing, washing, etc.). The study was prompted by an observation that people in Mtopwa rely on the Luchenza River for their domestic water requirements. A survey that was conducted in the area as part of the study showed that 3% of the population in Mtopwa used the water in Luchenza River for drinking purposes without any form of treatment. The study also showed that there was no provision for the disposal of liquid and solid wastes in the area. In addition, very few households had any toilets.

Analysis results of the water in the Luchenza River showed that the water was grossly polluted with faecal bacteria, although the physical and chemical parameters conformed to World Health Organization (WHO) standards for drinking water.

The paper discusses the significance of the problem, and looks at possible solutions in terms of quality and quantity of drinking water supply for Mtopwa residents, as well as sanitation aspects in the area.

Setting of National drinking-water standards: Malawi case study

V.H. CHIPOFYA & F.M.C. MSISKA

Department of Civil Engineering
University of Malawi - The Polytechnic, P/Bag 303, Blantyre 3. Malawi

vchipofya@poly.sndp.org.mw

ABSTRACT

This paper reviews the process of setting national drinking standards. All too often, developing countries adopt international standards for drinking water quality. In most cases, this turns out to be to the disadvantage of these countries in that much of their drinking water supplies will be inferior when related to the international water standards. Sources may therefore be unduly condemned, particularly when it is considered that these same sources duly support the local population without any instances of waterborne diseases.

The primary aim of setting national drinking water standards is the protection of public health, and thus the elimination, or reduction to a minimum, of constituents of water that are known to be hazardous to the health of the community.

The paper outlines the priorities to be taken into account when setting drinking water standards. These are availability, microbiological quality, chemical quality and physical and aesthetic quality.

The paper goes through the process of selecting contaminants for setting standards. The paper further reviews the quality of drinking water from varied sources within the country. It also considers the format and structure of standards incorporated in legal instruments for the country. This culminates in drinking water quality data for the whole country which was analyzed statistically using Microsoft Excel.

Stakeholder participation in the new water management approach: a case study of the Save Catchment, Zimbabwe

Dumisani DUBE and Larry A. SWATUK

School of Government, University of the Western Cape, Private Bag X17, Bellville, 7535

ebudumisani@hotmail.com

ABSTRACT

The 1998 Zimbabwe Water Act introduced the idea of 'lowest appropriate authority' in the management of water resources. To this end, the country has been divided into 7 catchments. This new set-up is intended to achieve efficiency, accountability and sustainability through stakeholder participation. This paper critically examines the idea of 'stakeholder participation' in the new water reform process. In this paper we council against an uncritical or atheoretical understanding of 'participation'. To simply assume that inclusivist language translates into wider benefits for society is to ignore the profoundly political nature of the entire water reform process. Water reforms cannot be separated out from land reforms. Neither of them can be understood outside of society-wide structural adjustment policies.

Keywords: *participation; stakeholder; water resources management; gender*

1. INTRODUCTION

> Institutions are both barriers to and opportunities for ecologically sustainable human development. Institutions can pervert or empower human potential.
>
> ■ Dovers (2001: 215)
>
> *'Kutu useke munhu achimhanya hunge wamuona achimhanya'*
>
> ■ a rural elder quoted in Sithole (n.d.: 8)

Water reforms are well underway in Zimbabwe. They are long overdue. The history of water use in Zimbabwe mirrors abiding problems over land. Yet historically derived inequities are seen to be but one of nine factors behind the reform process (WRMS, 2000: 7-8). The others are: too many actors/institutions and too little coordination; increasing competition for a scarce and finite resource; generally poor water resources; declining quality of that limited resource; lack of state-generated finance to adequately run the sector; lack of a common policy/benchmark by which to judge actions in the sector; a narrow band of stakeholder involvement in the sector; and recurrent drought on a large scale. Unacknowledged by the state, but equally important motivating factors include the general trend toward decentralisation fostered by neo-liberal approaches to resource management and current donor fascination with transboundary and community-based natural resource management, popular participation in decision-making and water 'security'. To ignore these last two sets of factors is to misunderstand the political and highly contestable nature of current reforms.

This paper focuses on stakeholder participation in the water reform process. In the Executive Summary to the WRMS document, *Towards Integrated Water Resources Management* (2000: 1-6), the word 'stakeholder' is used 14 times. 'Stakeholders' are defined as 'persons, groups or institutions with interest in a project or programme who may be affected in positive or negative manner by the decisions and actions made. This definition includes both winners and losers and those involved in or excluded from decision-making' (p. 111). A few paragraphs later it is suggested that 'opportunities for the participation of the marginalised groups are created and safeguarded' (p. 111). Women are singled out for special mention: 'A failure to provide adequate opportunities for the equal participation of women in the management of water will compromise the long-term objective of the development and efficient utilisation of the resource' (p. 112). Along with enhanced involvement of the 'stakeholder' is the expressed desire to see water managed at 'the lowest appropriate level' (p. 10).

What do all these things mean? How do such statements translate into policy and practice? In this paper we present some initial ideas regarding the ways in which participation and stakeholder involvement are being built into the water reform process. Our argument is that the drive to involve 'stakeholders' at the 'lowest appropriate level' emanates from two very different conceptualisations of 'participation' – one neo-liberal, the other participatory-democratic; one directing from the 'top', the other reacting primarily, but not only, from the 'bottom'. There is much more to water reform in Zimbabwe than 'getting the institutions right'. As Dovers points out, 'Institutions are defined more by the past than the present – they change slowly for the most part, and are more often suited to yesterday's understanding and imperatives rather than those of today, let alone those of tomorrow' (2001: 215). In the Zimbabwean context, such a claim has ominous undertones; to turn away from them is to undermine possibilities for meaningful reform.

2. PARTICIPATION

2.1 In theory

In Dovers' words, 'there has been increasing interest over recent decades in political and critical theory in more inclusive, participatory ways of "doing" policy and politics, often expressed in opposition to the countervailing trends of marketisation and globalisation' (2001: 222). However, ideas regarding 'participation' also grow out of these trends – that less state intervention means freeing up civil society to participate openly in the market. Such a powerful belief is being exported to the developing world via 'globalisation'. Dominant (donor) states, companies, and individuals benefit directly from 'liberalising' structural reforms. Target states and regimes struggle mightily to retain influence and control. While liberal theorists argue that 'citizens' are more likely to participate when they 'see direct benefits', it is more likely that they will get involved when they 'see some aspect of their "way-of-life" threatened' (Oliver, 2001: 266).

Liberal language depoliticises the reform process: 'trust' will build 'social capital' which are 'networks of cooperation'. Perhaps, but first we must arrive at trust. In present day Zimbabwe, there is very little trust indeed. Institutional reform built around a uninterrogated language of 'trust' may do more harm than good. If people are really interested in equal access to water resources – as many are – they must recognise the multiple agenda surrounding 'reform' and acknowledge that positive change, as always, emerges out of struggle.

2.2 In practice

In Zimbabwe, the impetus for participatory, stakeholder-'driven' water reforms emanated not from the poor and marginalised but from the top, i.e. from the national government, international donors and financial institutions (WRMS, 2000: 7-10; GTZ, 2000: 11). Motives, of course, varied greatly. One should not be deluded into believing that altruism is at the root of this project, inclusivist language notwithstanding. Evidence from CBNRM projects illustrates how the language of cooperation, participation and devolution often masks intended outcomes of renewed state and/or vested interest power (Twyman, 1999). Thus, 'participation' through 'partnership' is too often neither.

In terms of water reforms, one must recognise that structural adjustment conditionalities informed by global neo-liberal economic 'logic' underpins the entire exercise. Why would a central state voluntarily devolve – not merely decentralise – power over a crucial resource if it wasn't both economically bankrupt and politically powerless to resist those pushing the 'marketisation' of water? In the rush toward 'lowest appropriate authority' over water (via self-financing through user pay levies) states create the context within which those already empowered may combine de facto economic power with de jure political authority, i.e. the right to determine who gets and retains a water permit. At the same time, those at the margins of power may ultimately lose existing access because they cannot pay for resources they have historically used for free. Hence, in the vernacular, mining companies and commercial farmers (black and white) become 'stakeholders' and communal farmers become 'free riders'. Is this the case in fact?

2.2.1 Mazowe Pilot Project Experience

At the moment it is very early days in the life of the new water hierarchy. It is therefore unfair to draw any hard and fast conclusions. Nevertheless, certain trends are emergent. The Sanyati and Mazowe Catchment areas served as loci for pilot projects. Their perceived 'success' encouraged government and donors to fast-track the other five catchment councils. So, instead of 6 months to get themselves organised, the Save CC was given 6 weeks (Latham, interview, 28/06/01).

What kind of 'success' was achieved in the pilot projects? Interesting evidence may be drawn from two different accounts of the Mazowe Catchment Council (MCC). On the one hand, the GTZ report on the history and lessons learned from the formation of the MCC (GTZ, 2000) provides a relatively balanced view of the exercise. It might be termed 'cautiously optimistic'. On the other hand, Sithole (n.d.) is far more critical. Both reports use 'stakeholder participation' and 'equitable access' as benchmarks for assessing the 'Mazowe experience'.

In its Executive Summary (2000: 8), the GTZ document highlights 'important lessons learned'. For example, (i) complete honesty in an atmosphere free of politics… helps people to be more sensitive to the needs of other participants; (ii) low levels of public awareness impact negatively on stakeholder participation; and (iii) if the perceived objective of 'development' seems unlikely to be achieved, cooperation and participation from the communal sector diminishes or disappears.

Notably, aside from claims that 'the resultant working atmosphere was very constructive' and that 'black small-scale communal farmers and the white commercial farmers have formed harmonious working relationships' – no small achievements – there is little evidence in the document to suggest that 'success' at the pilot level warranted fast-tracking the other schemes. Where 'participation' is concerned we give but one example. A large workshop was held on 3 July 1996 in Bindura 'to *inform* a wide cross-section of stakeholders about the proposed changes in the water sector and to *gain support* for the Mazowe Pilot Project' (p. 11, our emphasis). 74 people participated with 36 from government, 18 from the private sector, 2 NGOs, 6 chiefs, 1 chief's aid, an independent farmer (1 of 4 women at the meeting), 5 from various user groups (CFU, ICFU, NILC, PIB), 1 teacher, 1 journalist and 3 from GTZ, the donor. While an improvement on what might normally have ensued, 'representation' in this case resembles an inverted pyramid. How then are we to interpret lessons learned ii and iii above? How might those six chiefs and that one woman farmer have felt among so many 'suits' in Bindura?

Sithole provides some insight. The second epigraph to this paper translates from the Shona as: 'To laugh at a running person, you must have seen them running'. In the context of catchment council formation in particular and water reforms in general, the essence of this is 'How can we assess proposed reforms if we have not been part of the planning process? For Sithole, '[I]n a situation which, historically, development of water has favored one group against another, one wonders what kind of cooperative behaviour can evolve among the actors' (n.d.: 6). To take her observation further. The Mazowe Catchment was chosen as a pilot project in part because it 'had a history of *decentralised* catchment-based management and had already formed a *private-sector-driven* "Mazowe River Catchment Development Company" when the Water Sector Reform began' (GTZ, 2000: 11; our emphasis). This company comprised 'an existing fully-functional rightsholder-based water management system for surface water with seven River Boards operating under the umbrella of a

Catchment River Board' (ibid). Decoding this sentence, the interests and management experience of white commercial farmers were to provide the framework for the pilot project.

This is how smallholders themselves understood the 'reform' process. At Nyadiri Sub-Catchment consultative meeting (13/10/99), Sithole reports that 'the "so-called" involvement in the water reform process came as a surprise to chiefs' and that 'Most chiefs expressed the sentiment that they did not understand why they were invited' (p. 10). One RDC official stated at Nyagui Catchment Council meeting (06/10/99), 'the new and proposed system changes nothing, those with money to build dams still have a comparative advantage over those in communal areas who have no hope in hell of ever building and sustaining one' (p. 9). In our experience with the Save CC, it is clear that CFU and ICFU members have taken to the Catchment Council like a duck to water. As with the Mazowe experience, black and white commercial farmers have formed a relatively stable alliance in defense of their common interests: access to water permits. From this perspective, the CC resembles a special interest group.

In her analysis of the dynamics of various 'stakeholder' meetings, Sithole observes, 'the relationship between different categories of stakeholders has been one of domination and acquiescence. Political history and the institutional framework has in the past and continues in the present to perpetuate these dominance/subordinate relationships between groups and sectors. Consequently, to understand the nature of participation by particular groups, one must appreciate the cause of centralism that preceded it' (p. 15). According to Sithole, it is as if the 'mere presence by a particular stakeholder group was all it takes to have the so-called "consensus" decisions on management' (p. 15).

Donors keen to observe 'participation', then, found it at the Mazowe consultative meeting. Indeed, one key informant who was a central player at that meeting, said to us that while 'whites have experience in managing water' so tending to dominate, stakeholder consultations over the course of the WRMS process were 'unbiased, focused, and facts-oriented'. In the rural areas, he said, 'debate is better than in parliament'. In his informed opinion, the pilot catchment experience 'percolated right to the ground' (interview, 22/06/01). However, it is useful to keep the image of the inverted pyramid in mind.

2.2.2 The Save Catchment

The Save CC and SCCs have now been in existence for a little over two years, having held inaugural meetings in July 1999. One year later, however, they were still in very rudimentary form (interview, Murinye, July 2000). Beyond issuing water permits, it remains somewhat unclear what the CC and SCCs are to do, how they are to do it, how they are to finance their activities, and what is their relationship to the Catchment Manager and to ZINWA. In the words of one key informant, "the formation of catchment councils was just dumped on us" (interview, July 2000). In this situation, Provincial Water Engineer (PWE) Murinye was forced to use all of his staff toward operationalising the Save CC. Subsequently, he has become the Catchment Manager whose role it is to liaise with the CC and SCCs and to provide them with technical advice. Officially, he is an employee of the Department of Water Development (DWD), seconded to ZINWA.

Constitution and Objectives of the CC

Like Zimbabwe's other CCs, the Save CC is comprised of the Chair and Vice-Chair Persons (all men, actually) of the 7 SCCs. At the inaugural meeting of the SRCC (16/07/99) it was decided to co-opt Mutare City Council 'to bring Council membership to fifteen. This was in view of the fact that the City is a major consumer who can not be ignored' (minutes SCC1: 1-2). At that initial meeting, the Chairman, Provincial Administrator, D.C. Munyoro, 'went on to emphasize the importance of the task that lay ahead for the councillors in mind that Water management was a broad responsibility involving land, water and the people'. Munyoro went on to identify the SRCC's major challenges as the utilisation of 'water to eradicate poverty among the people of the area' and to 'protect and preserve' the Save River (ibid). Also at that initial meeting, Mr. D. Kagoro, DWD and National Coordinator, ZINWA, highlighted the overall objectives of the reform process: ‘i) equitable access to water by all Zimbabweans; ii) efficiency in the exploitation and utilisation of water; iii) strengthening of environmental protection in the exploitation and management of water resources; iv) improvement in the administration of the Water Act’ (SCC1: 2).

Representation

Members are ‘stakeholders’ drawn from the main user groups: Commercial Farmers (CFU, Farmers Associations); Communal Farmers (RDC, ZFU); Indigenous Commercial Farmers Union (ICFU); Resettlement Farmers; Small Scale Irrigators; Industry; Mining; Urban Councils; Rural District Councils. According to the Catchment Manager, these ‘stakeholder’ groups were identified by the provincial water ministry. Conspicuous in their absence from this list are groups who use water but do not consume it – national parks and tourism operators. However, CCs and SCCs are not closed forums; they remain open to representations from other groups and are themselves in a gestative condition. The trend has been for this list to be amended as each CC or SCC has seen fit (interview, Murinye, July 2000).

While CCs and SCCs appear more or less ‘inclusive’ one cannot underestimate the impact of certain *eminence grises* in the constitution and operation of these ‘new’ organisations. Two in particular bear mentioning: First, as Tillman *et al* point out, ‘It is no simple matter to change existing habits or planning/management schemes that have evolved over many years’ (2001: 320). The impact of the past on the present is clear in the Mazowe example above: vested interests, questions of race/class, privileging technical knowledge over ‘traditional’ ways of knowing – all of these things lie at the very heart of the ‘new water hierarchy’ in Zimbabwe. Second, and emerging out of the first point, present at every meeting are the power dynamics of a deeply divided society. Indeed, by having pre-determined the structure and scope of ‘reforms’, one might say that ZANU-PF is the best represented of all.

Finance

One of the primary aims of the reform process is to make water management self-financing. Commercial users are to pay for the raw water they use or store, and a levy for the general management of the water sector. Levies are to be collected by the CC ‘on behalf of ZINWA’ at the rate of Z$40/Ml per quarter for directly abstracted water and Z$19.70 per quarter for stored water (based on coefficient of variation and yield). Out of this pool of money, the CC/SCCs get back 7.5% to be used to ‘manage’ the (sub)catchment. ZINWA remains the provider of bulk raw water. At present, the tariff for raw water for commercial use is Z$270/Ml. Murungweni, for one, feels that water remains seriously underpriced (interview, June 2001). Levies are to be paid by all water permit holders. This includes ZINWA where the Authority owns and operates a dam.

For Nhidza (2001: 13), a fundamental problem with this set-up is the failure of the reforms to include local authorities’ water utilities. ‘Financial arrangements of local authorities are such that revenue collected from water bills is bundled together, in the same “basket” with revenue collected from rates for other services which have nothing or very little to do with water services’. This is tantamount to ‘financial indiscipline’ as revenue from water is used not to maintain or improve water delivery, but to subsidise all other activities. Thus, in terms of our case, the City of Mutare pays raw water costs to ZINWA for water it gets from the Pungwe River supply scheme. These costs are passed on to consumers and a sizeable profit is made. This profit is then used to subsidise all other Council activities. Without this steady supply of Pungwe River water, the activities of the Mutare City Council would grind to a halt. Indeed, in a telling interview with a key informant at City Council, it was revealed to us that City Council is having difficulty in encouraging residents to dispense with their water *saving* ways – habits developed over the drought years – and consume more water. Said the informant, ‘We have water to sell!’ (interview, July 2000).

Awareness and Outreach

One of the stated major goals of the water reforms is to involve people at the lowest appropriate levels in the management of the resource. While CCs and SCCs are the major forums for this activity, it is also envisioned that other, lower tiers will be involved and/or created, e.g. water user boards. If the water sector hopes to achieve its stated goals of equity of access, and effective, efficient and sustainable management, it is imperative that all users understand the 'system'. To this end, each CC and SCC is to have a 'training officer' whose task it is, in the words of the Save River Catchment Manager, 'to capture the wishes of all people and collate their wishes into a work plan'. Given that Agritex has the 'best network in the country', it was logical that the SRCC chose to employ someone who is both ex-Agritex and has worked with and understands the needs and problems faced by the ZFU. In Murinye's words, 'the commercial farmers union knows how to look after its own interests' (interview, July 2000).

The training officer, Mr. Joel Sithole, is a dynamic personality, clearly suited to the job. Both in discussion with him, and in reading his reports, it is clear that the task of imparting information and raising awareness over an entire catchment area is daunting. It is made more difficult by a lack of time, and human and financial resource limitations. SIDA-provided seed money is due to end in December 2001. Sithole, like the CM, is overworked and overstretched. It is not uncommon for the CC to simply off-load tasks to him. On the down side, the training officer's brief has enlarged to such an extent that very little 'training' is being done. On the positive side, however, in covering so much ground, the training officer knows the catchment and its concerns better than anyone. In other words, he is the 'thread' in the patchwork quilt of water reform in rural areas.

At outreach/awareness meetings, no matter the composition of the meeting, gender representation or venue, the same concerns are raised:[1] i) knowledge, i.e. an almost uniform ignorance of the water reforms that have taken place and worry over the implications of such reform; ii) money, e.g. concerns over levies, permit application fees and the like; iii) maintenance issues, e.g. borehole, dam and equipment repairs and their associated costs; iv) plow back and other direct benefits from payment of fees; v) an almost uniform desire for individual ownership if user-pay is to guide water project developments; vi) a long wish list of possible irrigation projects; vii) a near universal demand for more systematic and sustained assistance from government, at whatever level.

Catchment and Sub-Catchment Council Performance

The researchers attended either together or separately, several CC and SCC meetings. Based on a combination of personal observation, open-ended discussions with members of these councils, and a close reading of the minutes of the SRCC and Odzi and Pungwe SCCs, we note several trends regarding participation. The most obvious point to be made concerns the dominance of the SRCC by the Chairperson – himself the Eastern Region CFU representative -- and by white commercial farmers in general. It would be unfair to read anything into these management/participation styles beyond the strength, confidence and demonstrated self-interest of the persons themselves. Nevertheless, it is clear that this style of behaviour either shuts-out or intimidates non-white members of the SRCC. This point was made to us in conversation with several of these individuals. It was also clear in comparison with the more open and open-ended style of meeting held by the PSCC, where stakeholders are more fully represented, and at the OSCC meeting where the Chairperson was absent.[2] One should not underestimate the importance of these considerations especially where people with fundamentally different cultural backgrounds are brought together.

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[1] In a fuller paper we will deal with these observations in a more systematic way. Space limitations dictate against such an approach here, however.

[2] The Chairperson of the OSCC is also the Chairperson of the SRCC.

The SRCC and its SCCs have taken great pains to achieve racial balance at the top. So, of the 16 Chairs and Vice-Chairs, 8 are white and 8 are black. Gender representation, however, is heavily skewed toward males. The fact that CCs and SCCs are at an early stage of development is reflected in the issues discussed at meetings. Meetings are overwhelmingly concerned with organisational and budgetary matters: e.g. opening bank accounts, determining travel allowances, renting out office space, hiring training officers, acquiring vehicles (in this case motorbikes for SCC training officers), revising budgets, accurately accounting for expenditures, clarifying matters regarding levies and application fees for water permits. There was an openly expressed desire to not let the donors down and to 'get your houses in order'. Stated the CC Chair: 'My biggest problem is Z$ 1.2 million we need to account for' (29/06/01). While SIDA funding is due to end soon, the Catchment Manager feels that 'we are not yet sturdy on our own' (interview, 25/06/01). At this point, there is virtually no discussion of larger goals like 'eradicating poverty' highlighted by Munyoro above.

With regard to issuing water permits, a core task of the CC and the stated 'barometer' of both stakeholder participation and management at 'lowest appropriate' level, the requests for permits that were granted at the CC meeting we attended had been previously submitted to, vetted and approved by ZINWA.

3. DISCUSSION

3.1 Defining 'participation'

If Mutare City Council does not attend a CC meeting but Chief X does, can we say with confidence that community X, represented through the Chief, is participating while Mutare City Council is not? Similarly, if a mining company or a tea estate does not attend a SCC meeting, but a smallholder farmer on behalf of his cohort does attend, can we say with confidence that smallholders are more assured of continued access to water than are mining companies or tea estates? These are important questions. The new water architecture not does address abiding power relations in Zimbabwe: mines and tea estates, as generators of foreign capital, have influence and therefore will have water. Claims to the contrary notwithstanding, communal farmers will continue to have more erratic access to this resource.

What is becoming clear is the strategic alliance that has formed between large scale and small-scale commercial farmers, irrespective of race. The GTZ report on the Mazowe experience mistakes this cooperation as 'beyond politics'. It is, in our estimation, profoundly political. Threatened by the 'resettlement' process, commercial farmers have chosen to work together. The political nature of this cooperation is further demonstrated in the very vocal frustrations expressed by CC and Pungwe and Odzi SCCs at the infrequent or non-existent attendance of Mutare City Council at meetings. Indeed, Pungwe SCC is a more infrequent attendee at CC meetings, yet they are never chastised.

City Council does not regard its absence as a problem: 'We will attend when we have a problem', said the city engineer in a interview. This seems perfectly reasonable, given the general content of CC and SCC meetings at the moment: dam maintenance and establishing telephone lines and post office boxes are issues fairly remote from the many pressing concerns of Mutare City Council. At the same time, Mutare's water supply is guaranteed via the Pungwe pipeline. For this they pay ZINWA. As long as fresh water supply is assured and CC and SCC meetings concentrate on organisational and/or fundamentally rural matters, the City Council will remain on the sidelines.

There are many other reasons why Mutare City Council should attend these meetings: the way they use water to subsidise other activities; the fact that the City cannot account for more than 50% of delivered water; the pollution that occurs from industrial, urban and peri-urban waste. If the CC is to manage its resources sustainably, these issues must be dealt with. Until they get beyond problems of organisation, they will have neither means nor reason to compel Mutare City Council to attend.

3.2 Gender issues

According to Ms Manyau, the only female Odzi sub-catchment council member, gender imbalances must be taken seriously as women continue to be sidelined even though they do most of the water related work (OSCC1). According to Murungweni, there are few women participating in formalised water management structures. For example, the SRCC has no female representative; the Odzi SCC has one. Both have female secretaries whose presence serves to reinforce traditional gender roles rather than challenge them.

Various 'cultural' reasons have been put forward to explain the absence of women in formal structure decision-making roles. Murungweni suggested that women tend to prefer having men occupy visible leadership roles. Murinye suggested that female participation is circumscribed by inconveniences of travel. Sithole stated that the timing of meetings tends to overlap with household duties. In his view, women cannot compromise their household duties for council meetings.

Women's public participation is clearly more prevalent at awareness/outreach meetings which, in a sense, brings 'government', via the training officer, to the people. At these meetings women often outnumbered men, sometimes by as much as 4:1. Irrespective of gender balance, the same issues and concerns appeared again and again. These are the same issues as those expressed at SCC and CC meetings: money, maintenance, a wish-list, a request (communal areas) or outright demand (resettlement areas) for government help. Are these the interests of women? Of women on behalf of communities? Are they the interests of men who determine the agenda and direction of meetings? Are they an expression of the interests of the training officer? Are they a community-derived list of grievances and worries trotted out whenever government pitches up? Given how these issues arise again and again whether women are present, a minority, a secretary, a large majority, or an angry group of demonstrators, begs the research question: are women adequately represented in the new water hierarchy in spite of their absence at formal, senior levels? Moreover, does 'representation' equal empowerment?

3.3 Parallel processes and overlapping jurisdictions

At an intellectual level, it seems obvious that for water resources to be managed sustainably the institutional framework should match the nature of the resource itself: so, river catchment = catchment council. However, CCs overlap with many political and sectoral jurisdictions. Manyame catchment, for example, comprises 3 provinces and 7 districts. Add to this a dense web of DNR, Agritex, NGOs, mines, urban councils and others active over the entire region. Coordination and inter-sectoral competition are major problems. None of these groups will submit to the will of the CC, especially one seen to be dominated by the special interests of commercial farmers.

Further complicating matters, the ZINWA-CC-SCCs-WUBs hierarchy is only concerned with the commercial use of *surface* water. Provision of potable water and water for sanitation purposes in rural areas is the concern of the Ministry of Local Government whose focus is groundwater. What is developing are two types of councils (CC and RDC) and two types of councillors. In theory there is to be synergy between the two groups. For example, Mr.Mpingo, Provinicial Administrator in the Ministry of Local Government, coordinates the Integrated Rural Water and Sanitation Supply Programme (IRWSSP), and is the local authority 'stakeholder' on the SRCC. According to ZINWA's Mr. Nyabodza (interview, 28/06/01), there is coordination between CC/SCCs and the Local Government-driven IRWSSP. However, it seems to us that this coordination exists only at the top and is marred by institutional and personal support for the status quo.

4.THE SPANNER IN THE WORKS

'Water and land are indivisible'. 'You cannot sustainably manage water resources without sustainably managing the land'. These are platitudes the researchers encountered again and again – in public forums, in interviews, in closed meetings, in official primary sources and secondary literature. To be sure, there are numerous aspects of water resources management that can be dealt with without reference to the single-most important question growing out of these platitudes. This question, like the Zimbabwean state itself, is everywhere and nowhere in the water reform process: What about land?

Land invasions, fast-track resettlement (legitimate and genuine; illegitimate and opportunistic), the displacement of farm workers, the diversion of government funds and technical assistance to ‘war veterans’, both real and imagined, the environmental problems associated with the unmanaged movement of peoples into carefully managed watersheds, the highly politicised nature of all aspects of land reform – these issues lay just below the surface lending a slightly surreal feeling to the entire water reform exercise, particularly to claims of equity and participation. In our case study, many SCC and CC members had been invaded. These land invaders were euphemistically referred to as ‘new users’ or ‘new occupants’. Statements like ‘all schemes must be referred to the Catchment Council’, that ‘users can’t do anything without a provisional permit’, and ‘water rights are allocated to the land, not the title holders, so, if there are new occupiers of the land, they must pay their levy’, all ring a bit hollow for the CC is powerless to act on them.

Zimbabwe’s water reforms are a bold experiment rife with contradiction. It does no one any good to deny the complicated and highly political nature of the process. Neither is it useful to analyse problems and progress without openly acknowledging the profound stress placed upon all of society by the uncertainties of land reform. Far from a united front, our research shows that ‘stakeholders’ are actively seeking self-preservation: the use of the CC as a special interest forum; Mutare City Council’s non-participation; central government’s desire to install a self-financing user-pay structure; inter-sectoral and intra-governmental jockeying for position; rural people’s desire for more and better government support; a Catchment Manager and Training Officer caught in the middle of it all. This is the true nature of ‘stakeholder participation’ in a deeply divided society. One can admire the SRCC Chairperson when he boldly claims, ‘They haven’t saved Save… We will.’ But a more fundamental and difficult question remains unanswered, ‘Who will save Zimbabwe from them?’

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Defining thresholds for freshwater sustainability indicators within the context of South African water resource management

GODFREY, L. and TODD, C.

Environmentek, CSIR, PO Box 395, Pretoria, 0001.

lgodfrey@csir.co.za

ABSTRACT

Indicators are an important means of assessing the performance of economic, social and environmental aspects, with the advantage of being able to summarize, focus and condense information about complex systems. Indicators highlight trends or phenomenon, which are not immediately detectable through basic data collection. However, there is often limited benefit to selecting indicators and implementing information collection programmes to populate these indicators, if indicator thresholds or benchmarks are not or cannot be defined. Thresholds are essential in assessing the relative degree of change in the indicator, when the carrying capacity of the resource has been exceeded, in setting management objectives for the resource and in assessing when goals and objectives have been achieved. This paper presents a methodology to define thresholds for freshwater indicators using the principles of the South African National Water Act (Act 36 of 1998) and the Department of Water Affairs and Forestry's (DWAF, 1999) Resource Directed Measures (RDM).

Keywords: *Freshwater indicators; thresholds; water resource management; reserve; classification system.*

INTRODUCTION

This paper presents a methodology for defining system and management thresholds for freshwater indicators, based on the principles of the Reserve and the Classification System defined in the South African National Water Act (Act 36 of 1998).

INDICATORS

The Organisation for Economic Cooperation and Development (OECD) defines an indicator as 'a parameter, or a value derived from parameters, which provides information about a phenomenon. The indicator has significance that extends beyond the properties directly associated with the parameter value' (OECD, 1994). Historically the term "indicator" has progressed from a broad definition to more pertinent definitions as the need for this strategic tool became more apparent. This is reflected in the following definitions for indicators:

- An indicator is defined as a "statistic or measure which facilitates interpretation to a standard or goal" (EPA, 1972).
- Indicators measure progress toward goals, milestones and objectives. They provide information on environmental and ecosystem quality or give reliable evidence of trends in quality (EPA, 1996).

- Indicators can present information on status or trends in the state of the environment, can measure pressures or stressors that degrade environmental quality, and can evaluate society's responses aimed at improving environmental conditions (EPA, 1996).
- Indicators are a valuable tool that can be used to measure the progress made in achieving sustainability (Tencer & Peck, 2000).
- Indicators are 'executive summaries' addressed to non-experts who want to get a quick impression of basic trends without the need for further interpretation (Jesinghaus, 2000),

Indicators have been adopted in a number of projects in South Africa, amongst others:
- The River Health Programme (Ballance et al, 2001)
- National, Provincial and City State of Environment Reports (DEAT, 2001).
- Rand Water's Catchment Indicators (Rand Water, 2000)

THRESHOLDS

According to Lancker & Nijkamp (2000), "A given indicator does not say anything about sustainability, unless a reference value such as thresholds is given to it. To be able to assess the actual state of sustainability or future outcomes of scenarios, critical threshold values are needed. These are values that cannot be exceeded without causing unacceptably high damage and risk to the environment." Thresholds are defined by Binedell et al. (1999), as "the level, beyond which a system (ecological or social) enters a different state or irreversible change occurs".

Three types of thresholds may be defined within the freshwater environment, those referred to as 'critical thresholds' or the "point, beyond which, the ecosystem will not be able to recover to its natural equilibrium state, or even to an acceptable or desired equilibrium" (Roux *et al.* 1999). System thresholds, which define a change in state of the water resource and are typically unique to a specific aquatic ecosystem or river reach, and 'management thresholds', thresholds which are used to define the proposed management level for the water resource. Management thresholds may very often be based upon system thresholds.

Thresholds are set through an understanding of :
- System conditions of the water resource, including, reference conditions; present state; desired state; achievable state.
- Management objectives and goals for the catchment or water resource; and
- National and local policies, plans and programmes.

Thresholds are dependant upon a number of factors (Binedell, 1999), including:
- The availability of both scientific data and subjective policy criteria;
- A degree of professional judgement;
- An understanding of processes, systems and cycles;
- Identification of specific resources within the system; and
- An understanding of the extent or significance of environmental impacts to a system.

Thresholds are often difficult to define as they require quantification of a resource for which there is often very little understanding, or very little data available. The South African National Water Act (Act 36 of 1998), provides a platform from which to develop indicator thresholds. In particular, the concept of the Reserve and the Classification System for freshwater resources.

The Reserve is defined as "the quantity and quality of water required to satisfy basic human needs and to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource" (National Water Act, 1998). Based on this definition, the Reserve can be seen as a system threshold for a water resource. A level below which basic human needs, ecological integrity and water services are compromised and the long-term sustainability of the water resource is placed in question.

A classification system has been developed by the Department of Water Affairs and Forestry (DWAF) that allows the water resource to be classified according to the degree of risk that will be tolerated for the resource and the level of protection required. Depending on the ecological importance and sensitivity of the resource as well as the amount of risk allowed, a resource can be classified into a desired management class representing a target or desired condition of the resource for long-term protection and management. In order for water resources to be protected, Resource Directed Measures (RDM) allow for a certain level of protection to be realized which will ensure sustainability of the resource. In order to reach or maintain this level of protection, goals or Resource Quality Objectives (RQOs) for the particular water resource are agreed upon, in terms of the quality, quantity, habitat integrity and biotic integrity of the resource. These numerical or descriptive statements translate into manageable goals for each of the four classes of desired ecological integrity of the resource. The classification system and associated resource quality objectives provide a means for defining management thresholds for the water resource. Classes A-D can be seen as management levels with an associated, varying degree of 'risk' to the integrity of the aquatic ecosystem.

Proposed Threshold Model

Based on the principles of the water resource classification and reserve methodology, as presented in the South African Water Act (Act 36 of 1998), the proposed threshold model is given below (Figure 1), followed a working example (adapted framework) of its application in water resource management (Figures 2).

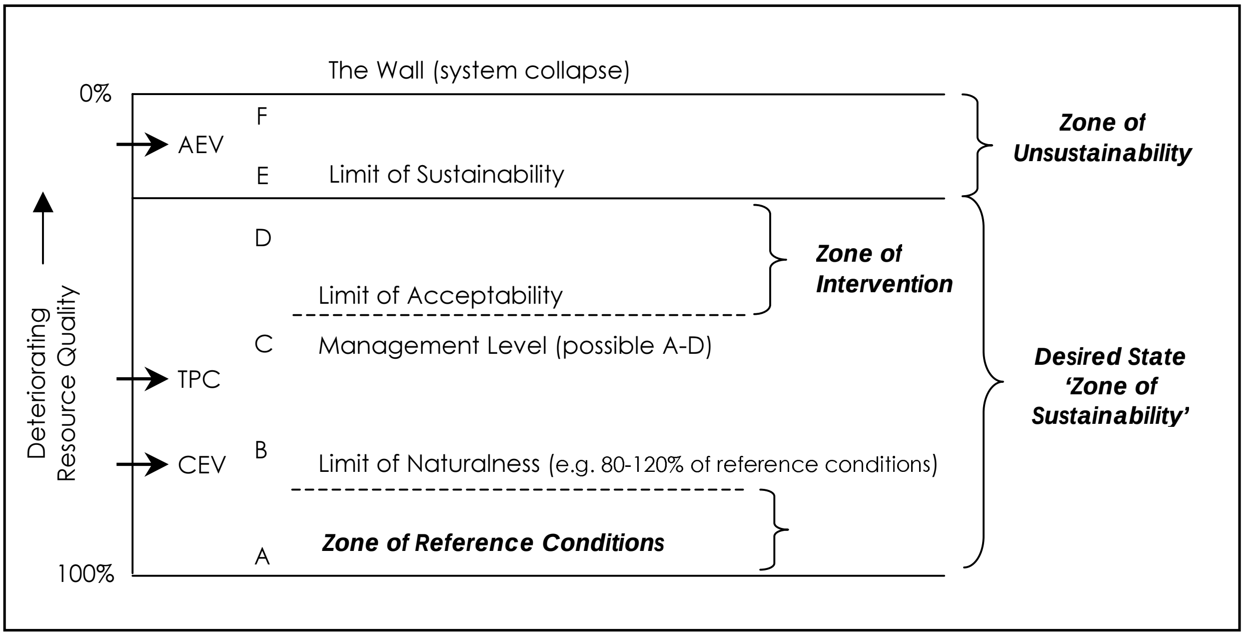

Figure 1. Proposed Threshold Model (adapted from Binedell, 1999).

The *limit of naturalness* defines the upper threshold for the zone of reference, or unimpacted conditions of the water resource. It includes the natural fluctuation or variation within the system, which defines the reference conditions of the system. Reference conditions vary both spatially and temporally for a water resource, catchment or river reach, resulting in a range in natural conditions.

The *desired state* is interpreted as that zone within which the water resource is sustainable. The Desired Ecological Management Class (DEMC) is set within this desired state or zone of sustainability and the water resource managed to this level with associated Resource Quality Objectives. The *desired state* of an aquatic resource reflects the desired ecological values that are sought or, the condition within which an ecosystem should be maintained. The current ecological status may be equal to the *desired state*, or a desired state may need to be achieved. In both cases, the *desired state* needs to be protected.

The *limit of acceptability*, although based on system conditions and criteria, is seen as the management level of the water resource. It is an objective statement of the desired state and should be set through scientific, stakeholder and management participation. According to Roux *et al* (1999), the limit of acceptability is based on three main issues, namely, (1) the designated water uses of the region, (2) the ecological conditions specific to a site or region, and (3) the resilience of that system to change. The *limit of acceptability* is also based upon the degree of risk which will be accepted by authorities and stakeholders, the degree of 'trade-off' between conservation and development. According to DWAF (RDM, 1999), a water resource may not deteriorate further that it's current state. The current state will therefore define the *limit of acceptability*.

The zone between the *limit of acceptability* and the *limit of sustainability* is seen as the *zone of intervention*. This is the zone within which management decisions and actions need to be made and taken to correct a declining trend towards unsustainability. For example, management actions may need to be taken to ensure that the river class does not deteriorate further, i.e. to maintain the chosen management level. This may entail curbing effluent discharge to surface water, and/or reducing the volume of water abstracted from the river for use.

The *limit of sustainability* is seen as the threshold at which the system becomes unsustainable. The *limit of sustainability* is seen as a system threshold. This limit is resource specific, e.g. river reach, species, geographical region etc. specific. Roux *et al* (1999) refer to this limit of sustainability, as the 'equilibrium point' in their 'Bubble-of-Stability Concept'. According to Roux *et al* (1999) the "edge or circumference of the bubble of stability represents a critical state. When an ecosystem is exposed to an overwhelming stress, the inherent resilience of the system is overcome and the system loses its stability. The critical ecological equilibrium has been altered, and the system enters a new equilibrium"

The zone between the *limit of sustainability* and *the wall* is considered the *zone of unsustainability*. Once an indicator crosses the *limit of sustainability*, the system will require major ecological engineering and financial investment, e.g. treatment and rehabilitation, to return it to a level of sustainability, if at all possible.

The 'Wall' – is considered that threshold at which the system collapses, a point of irreversible damage.

Thresholds may be set quantitatively by calibrating the y-axis of Figure 1. In terms of the Water Act, these quantitative thresholds may be defined by Resource Quality Objectives (RQOs) for the Reserve and for the management classes. Quantifying thresholds for 'acceptability' and 'sustainability' can prove difficult especially if the river is in pristine conditions, or if there is very little data available for a river reach. This is captured in the statement by Granholm (1987), cited in Hochberg et al. (1993), that "most natural thresholds are difficult to define until they are reached". Various approaches exist to quantifying acceptable levels of change, such as the 50% rule. Hughes (1995) for example, proposes that (1) 90% of reference conditions is considered of high quality and within the range of natural and measurement variability, (2) 75% of reference conditions is still acceptable, (3) 50% - 75% of reference conditions is marginal, and (4) less than 50% of reference conditions is unacceptable. Although a simplistic and fairly rigid means of assessing 'acceptable' and 'unacceptable' deviation from natural conditions, this is very often the only means of assessing the degree of change within a resource.

Additional thresholds, which have previously been used within the water field, prior to the reserve concept, may also be added to this diagram, to calibrate the y-axis. Such thresholds include:

- Water Quality Guidelines for varying water users.
- Acute effects value (AEV) – refers to the concentration at and above which a statistically significant acute adverse effect is expected to occur
- Threshold of Potential Concern (TPC) – In terms of the water environment, these can be defined as a set of end-points that describe the desired state in scientific detail and also provide the basis of a programme of monitoring for a wide range of biodiversity indicators (Rogers and Bestbier, 1997).
- Chronic effects value (CEV) – refers to the concentration limit which is safe for all or most populations even during continuous exposure.

Application of Threshold Model

Water Quantity

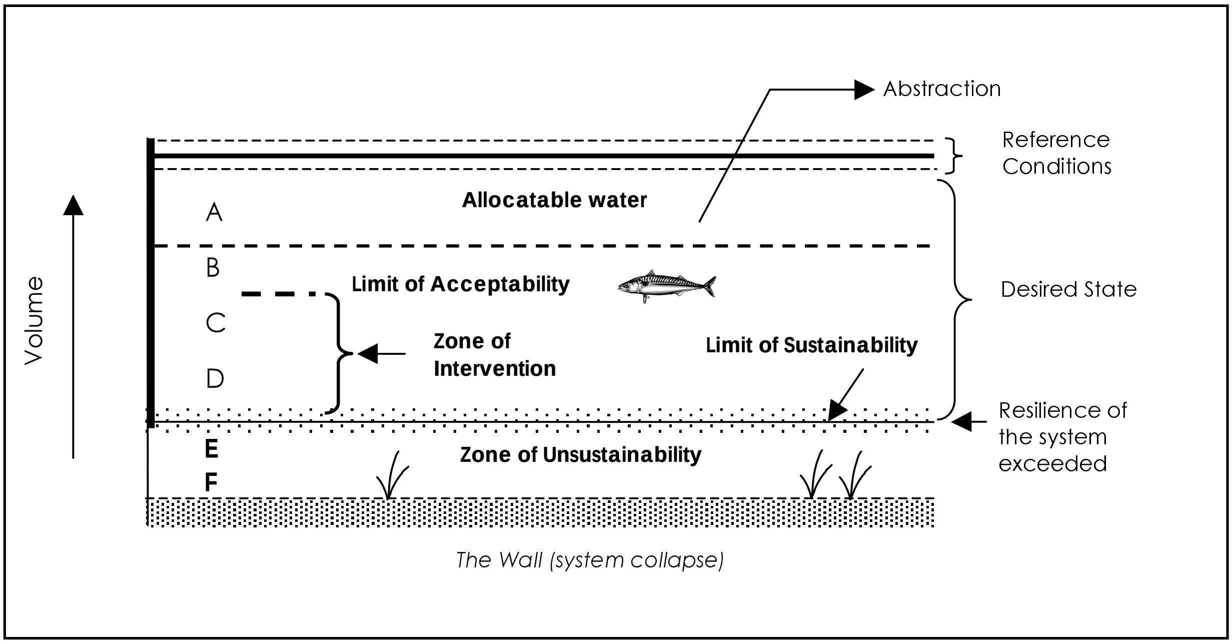

Figure 2. Example of threshold methodology as applied to a volume of water in a river.

If one thinks of this example as a section through a river, the following concepts can be defined:

- *The 'Wall'* or the point of system collapse, is the dry river bed, in other words where there is no water remaining in the river. The system although renewable, through for example a rainfall season, will have changed state, as the species number and diversity will have been affected by the loss of water in the river. To return the river to a sustainable ecological state would require some level of ecological engineering.

- The *Reserve* is that quantity and quality of water required to protect ecological integrity and to meet basic human need requirements. Within this zone, the resource can be managed at various desired states (Class A-D), depending on the acceptable level of risk to the water resource, and the demand for the water and the possible impacts of a proposed development on the water resource. The identified desired state of the resource is considered the *Limit of Acceptability* or management level. Irrespective of the chosen desired state, some degree of management or intervention will be required to ensure that the state does not deteriorate further. Should the acceptable state of the river be taken as a Class D, the *Limit of Acceptability* and the lower *Limit of Sustainability* would be one and the same.

- The volume of water in the river, over and above that volume required to protect the reserve, is considered 'allocatable water', water which may be used for purposes such as industry, mining, agriculture, i.e. water user requirements.

- The least impacted conditions are considered the reference, or unimpacted conditions of the river. This level will include some degree of 'naturalness', or fluctuation, depending on seasonal conditions.

- Depending on the desired or acceptable state (class) of the resource, RQOs or thresholds for the specific class can be set.

DISCUSSION

The indicator, '*abstraction volume with respect to allocatable water'*, identifies a measurable parameter, abstracted water, and relates this to a known 'fixed' system parameter, allocatable water. In so doing, the thresholds can be easily quantified, as shown in the following example.

Note: Classes and values assigned to limit's of acceptability and sustainability in the previous and following examples, are used for description only and should not be taken as prescriptive in any way.

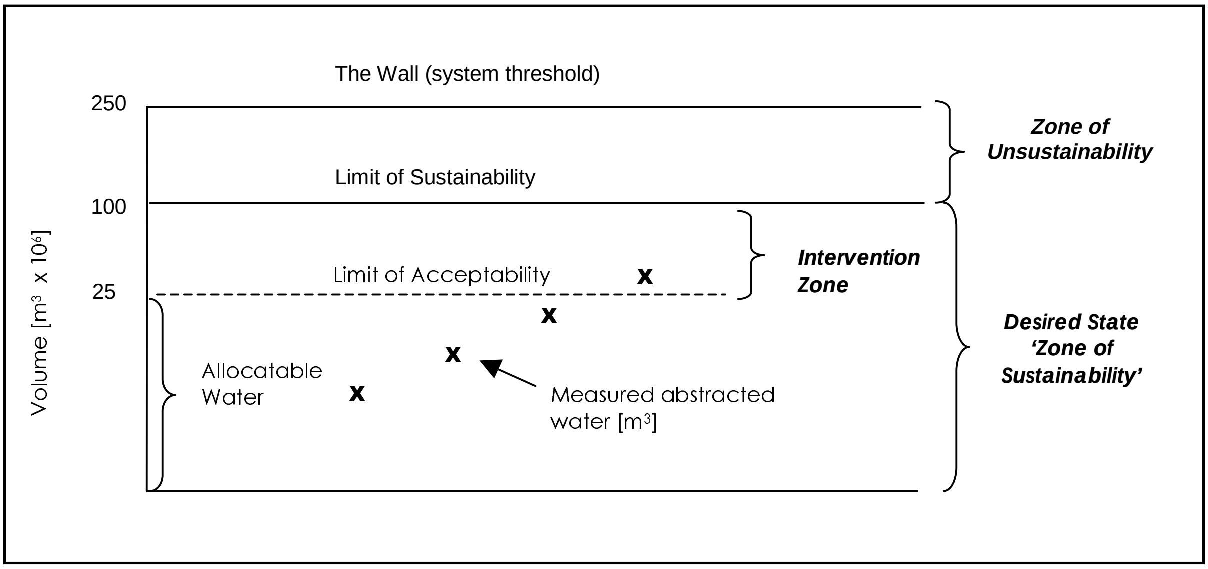

Figure 3. Threshold framework for indicator

In this example, the *limit of acceptability* is set as the volume of allocatable water. Fictitious values for the volume of allocatable water and the volume of the reserve are given for example.

The thresholds are defined as:

Threshold of Acceptability = $\frac{Abstracted}{Allocatable} = 1$ (where abstracted = allocatable)

Threshold of Sustainability = $\frac{100}{25} = \frac{Abstracted}{Allocatable} = 4$

System Threshold = $\frac{250}{25} = \frac{Abstracted}{Allocatable} = 10$

The absolute, measured value (abstracted volume) may be depicted graphically, however the ratio may be chosen for reporting on the state of the indicator, as shown in Table 1.

Table 1. Example of reporting on the state of the indicator

Date	Abstracted Volume $[m^3 \times 10^6]$	Ratio
January 2001	13	0.52
March 2001	18	0.72
May 2001	27	***1.08***

Threshold of acceptability exceeded

The exceedance of the limit of acceptability can be easily identified in this example in three of the six months, when the ratio exceeded 1.

CONCLUSIONS

Indicators provide a useful means of reporting on the state of South African water resources. However, without defining quantitative or semi-quantative management and system thresholds for these indicators, indicator monitoring programmes provide only limited information on the degree of sustainable management of our water resources.

The Water Act (Act 36 of 1998) and the Resource Directed Measures provide a platform for defining management and system thresholds for freshwater resources in South Africa.

ACKNOWLEDGEMENTS

The authors would like to thank the CSIR project team involved in Indicator and Threshold Research, namely Rob Hounsome, Liz Linnett, Michelle Binedell, Mieke van Tienhoven, Anna Ballance, Martin de Wit, Elizabeth Muller, Jeremy Evans and Melanie Wilkinson.

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The role of urban agriculture in food security: A case of low-income dwellers in Dangamvura[1]

Makhosandile GOGWANA

School of Government, University of the Western Cape, Private Bag X17, Bellville, 7535

mgogwana@yahoo.com

ABSTRACT

Changing economic conditions, increasing unemployment and increasing population pressure on urban centers have resulted in heightened food insecurity among low-income urban dwellers in Zimbabwe. In order to ensure food security, urban dwellers have now resorted to intensive use of water and land for the production of food for their livelihood. This paper intends to highlight the challenges and opportunities of urban agriculture and to examine the central role played by access to water resources therein. In our study of Dangamvura- a low-income suburb of Mutare, Zimbabwe – it has been identified that people are utilizing open municipal spaces and their yards to grow crops and vegetables for family consumption and as surplus to sell. This has opened a source of income and employment for low-income urban dwellers. People are utilizing water ear-marked by the municipality for primary use to water their small gardens and larger plots using open canals, buckets and hosepipes. In this paper we also outline how urban agriculture should be accepted as a legitimate form of land use and incorporated into formal urban development plans.

***Keywords**: food security; urban agriculture; water accessibility; off-plots and on-plots cultivation; Dangamvura; illegal cultivation; government.*

1. INTRODUCTION

This paper reports on research conducted in Zimbabwe to highlight the role of urban agriculture in food security. The paper aims to identify the challenges and opportunities of urban agriculture and the central role played by access to water therein. A case of Dangamvura, a low-income suburb of Mutare, Zimbabwe is presented. The paper then outlines how urban agriculture should be accepted as a legitimate form of urban land use and incorporated into urban development.

Two major observations have been identified: urban agriculture as an "opportunity" as well as urban agriculture as a "challenge". These observations provide a platform for key strategies and policy interventions to address some of the challenges and constraints of urban agriculture.

Urban agriculture in Dangamvura includes on-plot and off-plot land cultivation. On-plot land cultivation takes place within residential stands while off-plot land cultivation takes place on open spaces outside the residential stands on land perceived as idle land. In Section T, for example, people do not have enough space on their residential stands. As a result, they are using any available public open spaces, ditch and roadsides cultivation for crop production. Many different crops are produced: vegetable production such as lettuce, onions, cabbages, spinach, beetroot and strawberries; fruit production such as oranges, pineapple, bananas, mangoes, apples; and the production of flowers and poultry. Maize, beans and pumpkins and sugar cane are most often produced on larger plots either in open fields or some few kilometers away from the suburb.

[1] Footnote: Research made possible by a graduate scholarship funded by South African Water Research Commission (SAWRC). Thanks to the following research team members: Dr Swatuk, Dr Hara, Tawanda and Bevan.

2. THE BACKGROUND OF THE STUDY

The SADC Food Security Unit has reported that Zimbabwe is facing a food crisis. The country has been critically short of currency since 1999 due to poor performance of its primary commodity based export sector. Some of the poor urban families with access to land are currently harvesting their maize, but this will only last a month on average and they then have to rely mainly on market for their food (***Daily News***, 28 July 2001: 2). In Dangamvura there is widespread use of open municipal spaces and private yards to grow crops and vegetables for family consumption and as surplus to sell. Residents are raising animals and recycling organic waste into compost. In doing this they are utilizing water earmarked by the municipality for primary purposes for their small and larger plots, using open canals, buckets and hose pipes. However, this activity is not limited to Zimbabwe. In countries throughout the developing world millions of men and women are farming in cities (Nugent, Drescher & de Zeeuw, 2000).

2.1.Urbanization

The general nature of urban areas creates special circumstances for survival. This, combined with the peculiar historical circumstances in which Zimbabwean urban towns were built, makes life difficult for urban dwellers (Madondo, 1992). With the expanded population of the city, the provision of food has been critical and urban agriculture has increased as a possible solution. Rapid population growth in cities is caused by in-migration of rural people and by natural increase (estimated at 3.8 % per annum). Clearly, urban populations increase every year. However, in the context of general economic crisis, as is the case in Zimbabwe, city growth also means increased unemployment, gradual breakdown of basic social services, and increasing food insecurity. Urbanization is one of the major issues facing policy makers today.

2.2 Economic Conditions

Globally induced economic changes and/or crises and their effect at regional and national levels combine to worsen conditions for the urban poor. Zimbabwe’s deteriorating national economy and persistent political and socio-economic difficulties have led many people living in urban areas to pursue urban agriculture as a livelihood survival strategy. The burdens imposed on consumers by Structural Adjustment Programmes (SAPs) contribute significantly to these pressures (Jacobi, Axel and others, 2000). Market liberalization either reinforced by SAPs and/or national governments typically induce and directly affect national economies and local livelihood conditions through export oriented market reforms that raise basic commodity prices, currency devaluation that increases prices and cuts in food subsidies for urban consumers.

The short and medium term results of conditional programmes have put an economic squeeze on poor populations in developing countries who frequently resort to non-market (informal sector) activities for survival. Of additional concern for the households are decreasing stability and security in formal employment and decline in the real wage of urban workers. Urban food production is in many cases a response to inadequate, unreliable and irregular access to food supplies due either to lack of availability or purchasing power and inadequate access to formal employment opportunities, due to deteriorating national economies in developing countries.

2.3.The Dilemma

The balancing act between providing adequate shelter and economic opportunity against a backdrop of high urban unemployment compounded by a big school leaver population and increasing levels of malnutrition is a daunting task for most urban authorities. What are the chances of urban authorities utilizing all the land under their control to build houses or factories in the next ten years in view of money markets becoming tight? (Madondo, 1992: 5) Is this land not more profitably utilized by encouraging local residents to practice urban agriculture? Will not such cooperation between local/regional/national governments and ordinary citizens build trust rather than further break it down? Is this trust not an important commodity in difficult economic times?

3. URBAN AGRICULTURE ON THE POLICY AGENDA: A CASE OF DANGAMVURA

3.1 General Description of the Study Area

Dangamvura is a low-income suburb on the outskirts of the City of Mutare in Zimbabwe. Although it was difficult to obtain documented information regarding population, income levels, employment, and poverty levels, it is not inaccurate to say that Dangamvura is characterized by high levels of unemployment, increasing population and is in general, a low-income area. Most people within Dangamvura originate from rural areas. According to an Agritex study, 75% of people were born in rural areas and 25% in urban areas. This reveals that many people have an agricultural background (Madondo, 1992). Some people are immigrants from Mozambique, Malawi and South Africa.

Dangamvura is mainly a residential area with almost no formal economic base. Some local retail outlets and bottle stores that used to provide income for local residents are either closed down or no longer viable. There is a lack of maintenance of physical infrastructure such as roads and bridges. In general, there is a serious lack of local services, shops and other micro enterprises. As a result, most money that could be used to purchase goods locally flows instead to the City of Mutare. This means a missed opportunity for local entrepreneurs. The informal sector plays an active role and most people involved in this sector are women. Major activities are selling fruits/vegetables and firewood, operating shebeens and running spaza shops. Most key informants said that this sector is growing at an alarming rate as a result of decreasing numbers of jobs in the formal economy.

Social problems such as public drunkenness and theft both day and night are two major problems mentioned by most respondents. These problems were observed during my home stay in Dangamvura. This reveals an increasing economic insecurity among the urban dwellers resulting in negative social consequences such as theft. Urban agriculture, considered by some City Councillors to be ‘theft’, is in my view a positive response to economic insecurity.

3.2 Physical Layout of Dangamvura

Dangamvuara is divided into different sections such as Sections T, P, N and Sections, 12, 14, 15 and 16. The physical layout of Section T is different from the other sections. One key informant said that what makes Section T unique is its history as it is an old section built during the colonial era mainly for migrant labourers. Building structures are in the form of hostels (block structure). In most households, a family of five to eight share a dining room, one or two bedrooms (if extended), a small kitchen, and a flush toilet with water connection and shower. The yard is very small such that most households reserve a small space for chicken rearing. Only off-land cultivation on open spaces is used for vegetable gardens. People take water from public taps using hosepipes and buckets to water their gardens. For those public open spaces that are far from the water points, irrigation does not take place. The long distances from the water points make it difficult for most people to carry water to their plots. As a result most people wait for the next rainy season.

The other sections of Dangamvura have been built more recently. Most of them are government subsidized, privately built houses with water connections inside the house and bigger yards. Most people in these sections practice both on-plot as well as off-plot land cultivation. People have bigger space in their yards, which they can use to extend their houses or for other purposes. Most people prefer to use the space for gardening. People have bigger space in their yards in such a way that some households have grown fruit trees such as bananas, mangoes, guavas, pineapples, apples, and oranges, mainly for home consumption.

3.3 Forms of Urban Agriculture in Dangamvura

Despite the uniformity and generally poor quality of the housing especially the aforementioned T section of Dangamvura, people continue to use any available public space they perceive to be idle. Cultivation takes place in off-plot allotment and public areas such as along the rivers and roadsides.

3.3.1. “Illegal”(Maize) Cultivation

Along the Sakubva River, which is less than a kilometer from Dangamvura, people tend to grow mainly maize, which is usually consumed as green maize. There are a number of problems associated with this practice like stream-bank cultivation which results in soil erosion, water pollution and siltation of the river. Most respondents stated that they also have off-plot maize cultivation some kilometers away from the residential area. These areas are called Gimboki, Iquarry, Nyanyadzi, Pinto, Dora and some plots near the Sewage Treatment Works. In these areas maize is intercropped with beans and pumpkins. In some cases, people said that they share their block with neighbors but each portion is individually managed. In general, plots are cultivated during the rainy season. Respondents stated that ploughing is done by tractors costing between Z$500-1000 per block of cultivated land. However, most people said that slashing of maize by officials of the City Council of Mutare – often without notice -- has been common practice. In defense of this practice, key local government informants said that cultivation in these areas is ‘illegal’ as they are gazetted for industrial and residential development.

The problem of ‘illegal’ cultivation is not limited to Mutare but occurs throughout Zimbabwe. Most people are also cultivating maize and vegetables around the houses in open public spaces and this often leads to conflict between the Council and the urban farmers. However, this problem is currently being debated in parliament. The following is a quote from a member of parliament: “Year after year, these people are left to do all the cultivation, planting and weeding. When their crops get to maturity stage, the City of Harare sends people to slash their maize. In most cases they leave the tall grass along the roads and slash the maize. I think the City of Harare should think of how to control the cultivation because discouraging it does not work. People depend on those small fields. Some even harvest enough to take them through the year from June when they harvest to the following June”(Parliamentary Report, 2000).

3.3.2 Individual Vegetable Gardening Plots

Vegetable gardening is often done on clearly demarcated open spaces around the houses either by individuals or as a group. Individual plots are usually fenced, using for example old bedsprings, existing footpaths and sometimes trees. There are communal arrangements that are made by the growers. One respondent said that not everyone is allowed to have a plot if growers have “identified” the open space. For example, people whose residential stand is closer to the identified open space, are allowed to grow. They sometimes use corner houses to determine who is allowed to grow. Corner houses are often adjacent to open public spaces and make it possible to carry water by buckets from residential stands or use hosepipes to water vegetable gardens. Most respondents said that stealing of crops and vegetables is not a common problem. They strongly believe that if you steal someone’s vegetable or crop, you may either lose your hand or become sick. This is the case at Section T where most people have off-plot land cultivation because of the shortage of space in their residential stands. Most people use buckets and wheelbarrows to transport water to their plots. Some of the plots are located at the foot of the mountain, which make watering a difficult exercise. Most respondents mentioned "long distances" as a barrier to bucket irrigation, as water has to be carried from the residential stand to the foot of the mountain. A wide variety of crops are grown such as beetroot, carrots, cabbages, potatoes, tomatoes, pumpkin, onions, spinach, and of course maize. Most of it is grown for home consumption, but part of it is sold to the neighbors.

3.3.4. Vegetable Gardening in Farming Groups

Some plots 'belong' to a group of people and are managed by a group of growers. One example was a communally managed vegetable garden in the church premises of Zaoga Forward in Faith in Section C. According to the Pastor of the church, only church members are allowed to grow. Although all church members are allowed to grow, not all of them grow at the same time. Cultivation is rotational and dependent on the (good) will of individual church members. Officially, the land belongs to the church that has given it to its members to improve food security and to support income generating activities. Also, this type of cultivation commonly takes place in schools and clinics. In general, both of the above-mentioned cultivations are done on a very small scale as compared to off-plot allotment in Gimboki, Nyanyadzi and Dora. Space is definitely a limiting factor, as the yard has to serve several purposes. In general, all growers are responsible for policing the vegetable garden. However, one respondent said that the presence of a caretaker both day and night in most school and clinics is an effective deterrent to theft. Most people said that pests are one of the common problems in both forms of agricultural activities as not all farmers have equal purchasing power of pesticides.

3.3.5 Chicken Rearing

Some people also rear chickens, mainly for home consumption but also as surplus to sell. They use backyard shacks to keep the chickens. In my "home stay" three people came consecutively to buy chickens but unfortunately all of them had either been sold or consumed by the family. The chickens are often kept at the backyard shack. Chicken feed and sometimes mealie-meal is used to feed the chickens. Some respondents said that they sometimes take 1 bag of 50 kg of mill-meal to the grinding mill in order to feed the chickens.

3.3.6. The use of Fertilizer in Crop/Vegetable Production

Most people said that they use chicken manure as fertilizer for their crops. The Sewage Treatment Plant on the outskirts of the suburb also provides most farmers with fertilizer. They use wheelbarrows and buckets to fetch the fertilizer from the treatment plant which they get free of charge. One City Council key informant said that the City Council allows urban farmers to collect as much fertilizer as they can. The collection of fertilizer by urban farmers also contributes significantly to urban waste management. However, some respondents said that they buy it from street vendors and TM Market. To improve the fertility of the soil, they also add homemade compost from crop residues, green leaves and grass collected within and outside their gardens. Some respondents said that they plough back crop residues after harvesting to maintain the richness of the soil.

4. THE CENTRAL ROLE PLAYED BY ACCESS TO WATER IN FOOD SECURITY

The various uses of water in different sectors of an economy add value to these sectors. Similarly the use of water in urban agriculture adds value to this sector. The damage to an economy by water shortage may be immense. For examples, the drought of 1991/92 directly affected Zimbabwe's agricultural production which fell by 40% in 1991 and 50% in 1992. The country's population had to be given relief food and emergency water supplies through massive deep drilling programmes since many rural boreholes and wells dried up. Urban water supplies were severely limited with unprecedented rationing (Van der Zaag, 2000). As a result, a huge Water Supply Project was proposed by the City of Mutare to abstract water from Pungwe to the City of Mutare. Urban water supply is becoming an even more important source of livelihood and food security in most urban centers.

4.1 Water Pricing

With the declining economic situation and increasing levels of unemployment in Zimbabwe, paying for water is becoming a nervous condition in most people in Mutare. For urban farmers in Dangamvura, it means vulnerability to food insecurity, as they have to use minimize water use for their crop/vegetable gardens. Most respondents stated that shortage of water is not a problem: water is there for those who can pay for it. However, access to it is becoming a serious problem. Most respondents referred to water charges by the City Council, which they perceive as unreasonable. How urban poor farmers use various survival strategies to cope with these difficulties, as illustrated in 4.2 below.

4.2 The Case of Mr Hot Air

During the transect walk in Section P, I saw a very green, healthy vegetable garden. Various types of vegetables were grown such as cabbages, spinach, tomatoes, lettuce, damboos, beetroots and carrots. The garden, an on-plot vegetable garden, covered the entire front and side yard, and was marked by an elaborate set of irrigation furrows. Working on the garden was an old man. This garden drew my attention and I decided to come closer and ask permission for an informal interview with this old man. The first question was “Daddy, you have a very nice vegetable garden and it seems to be best of all the gardens I have seen so far. Tell me about your secret that makes your garden so beautiful and healthy.” The response was: “No problem, I can do that, provided that what you want is not going to put me in a ‘Hot Air’.” As an informal discussion was going on, I came back to the words “Hot Air”: “Daddy you mentioned an interesting term, what do you mean by ‘Hot Air’?” He replied, “Yes, I am not surprised why you do not know because it is a philosophical word.” His meaning became clear with time.

As the interview proceeded, I noticed a leaking drainage system just a few meters away from the fence of the vegetable garden. The source of the leak was a storm drain located just beyond his fence but adjacent to his vegetable garden. At the center of the vegetable plot was a dug hole full of water. The hole was about two meters deep. From the leaking drainage system there was a furrow diverting water to the hole. The water in the hole was used to irrigate the vegetable plot. The urban farmer said that the ‘plan’ is helping him a lot in terms of saving water because he does not have to use water from his in-house connection for his vegetable garden. Thus, he can afford to pay his monthly water charges to the City Council and reap a plentiful harvest for home consumption. He said that the City Council once fixed the leaking drainage. Thereafter he had to use metered water. Sometime later, however, the leakage began again and the respondent was quick to take advantage of this situation. His stated motive for masking the leakage was the high cost of water, which was unaffordable for them as pensioners. Mr. Hot Air’s case is not unique. This issue was also tabled in parliamentary debate on urban agriculture in November 2000: “Madam speaker, I want to thank the hon. member for moving this important motion. All urban dwellers know what agriculture is all about and what it is doing to some of our families who are getting poorer and poorer. The majority of them are now pensioners and on average, they get about $400 per month. Water bills average $500 a month and as a result, for them to survive, the only source for them is what they get from the small field” (Parliamentary Debates, Vol.27.No27, 2000).

According to Jacobi et al (2000), urban food production can be seen as a crisis strategy ensuring survival of the poorer segment of the population. Supporting the “crisis model view” are examples of people’s survival strategies during periods of economic decline and economic unrest in densely populated cities. Clearly, “Mr. Hot Air” was pursuing a survival strategy that, while successful, he feared might land him in trouble with City Council.

5. THE BENEFITS OF URBAN AGRICULTURE

There are two levels where urban agriculture should be seen as beneficial. The first level is the community level and the second level is the government. These levels play various roles but share a common goal of improving food security among the urban poor.

5.1 The Community level

The benefits of urban agriculture should not be underestimated in terms of improving food security among the urban poor. Most respondents mentioned that they are involved in urban agriculture mainly because it contributes significantly to household income and the nutritional status of the family, i.e. as a livelihood strategy. Most people said that urban agriculture provides them with fresh relish and they do not have to buy vegetables from the market. Sadza (pap) is a staple food for most people in Zimbabwe. Most respondents said that they do not have to buy mealie-meal from the market as they harvest sufficient maize from their off-plots in Gimboki, Dora, Pinto and Nyanyadzi. The produce takes them to the following harvesting season. One respondent was proud to show me fourteen 50kg bags of maize harvested the previous season. Some of the bags of maize are taken to the mill for grinding. The mill-meal serves various primary purposes such as sadza for the family, and feed for domestic animals. The grinding mill markets (TM market) also provide job opportunities for the local residents, thereby supplementing household income. Some people also earned money by selling fertilizers to the community. However, these jobs are few. Most respondents said they do not sell their produce to the market since it is small scale, but surplus is sold to the community. Some respondents said that they sometimes share their produce with their neighbors. Sharing plays a crucial role in terms of cementing relationships among community members. This promotes social cohesion and a spirit of oneness within the community. In terms of gender, urban agriculture benefits most women. Women are the most vulnerable section of the population in terms of food insecurity. In our case study, it was observed that women dominate this sector. However, this is not to say urban agriculture should be regarded as women’s domain.

5.2 Government level

It must be recognized that not only the community benefits from urban agriculture. Even the institutions that continue to persecute and relegate urban agriculture into informal activity can benefit. However, benefits will be realized only if this activity is promoted from the relegation zone. Urban agriculture must be recognized, legitimized and incorporated into urban development policy if benefits are to be widespread. People may stop cultivating along river banks and roadsides or will only cultivate appropriate and approved crops, like sugar cane, which helps to fix the soil. People may stop using water unnecessarily or “illegally”, getting it from leaking taps, leaving faulty drainage systems unreported or causing the leaks themselves. At present, these remain viable survival strategies for the urban poor. The objectives of water management at the lowest appropriate levels (Dublin Conference in 1992) may also be realized. This means, capacity building among the urban farmers will play an important role in water management. Self-management and legalization also helps relieve cash-strapped and manpower-short City Councils from such tasks. Urban agriculture also provides benefits in terms of greening the city.

6. THE CHALLENGES

Putting urban agriculture at the top of the policy agenda by local governments can be seen as a positive step towards achieving food security among poor urban dwellers in Southern Africa. Incorporating urban agriculture into the urban policy design can help spotlight some of the major challenges facing most local governments. As illustrated by our case study, the major challenges and constraints faced by urban farmers are access to affordable water and availability of land as most urban farmers mentioned shortage of land as a major obstacle. Problems of insecure access to these inputs plague urban farmers everywhere (Drescher et al, 2000). Specific land problems arise because town by-laws and regulations prohibit food production of certain types and because poor farmers are pushed off land that is taken over for development.

Unavailability of technical advice was also mentioned as a major constraint with most people farming without such advice. A key informant from Agritex stated that Agritex does provide technical assistance to farmers. The Ministry of Agriculture started this project eight years ago focussing on rural areas. The project is run by Extension Officers whose main activities are to provide training on various agricultural activities such as poultry, pot-flowers, rabbit rearing, dairying, bee-keeping, and crop/vegetable production such as maize, sweet potatoes, carrots, tomatoes, etc. The project involves group training and household visits. The intention is to build the capacity of the farmers. This project is also run in the peri-urban areas of Mutare such as Dangamvura, Sakubva, and Chikanga. However, he stated that people do not come in large numbers and most do not know about their services. He said that in these areas, stream-bank cultivation by urban farmers is the most common problem. He mentioned shortage of land and access to water as major reasons for people to cultivate in stream-banks.

7. CONCLUSION AND RECOMMENDATIONS

Whether we agree with the practice or not, urban agriculture is an important socio-economic activity particularly for the poor. Recently, local authorities and planners seem to recognize urban agriculture as an essential part of livelihood strategies of some social groups within the townships and as a way to address the issue of unemployment (Oudwater et al, 1999). It acts as a supplement to household income thereby reducing poverty and food insecurity. However, if not properly planned and incorporated into urban development policy, it will continue to have some negative effects in the form of, e.g., increasing environmental degradation. A degraded natural resource base ensures food insecurity for the urban poor. Criminalizing urban agriculture can also lead to negative social effects, like the deliberate destruction of water storage and delivery systems. High economic costs of “illegal” cultivation also may be realized, as governments have to employ more personnel for policing against “illegal” cultivation.

What needs to be done? The main tasks for governments, particularly at the local level, regarding urban agriculture include:

- Recognizing urban agriculture as an integral part of urban economy and as an important socio-economic activity.
- Ensuring that all urban councils regulate urban agriculture within their jurisdictions.
- Promoting, identifying, planning, setting aside and allocating specific areas of land suitable for urban agriculture.
- Providing water points for off-plot cultivation.
- Offering education and training in soil conservation, crop production and marketing strategies.
- Ensuring that urban agriculture is incorporated in all layout plans as a matter of policy.

In doing this, all urban councils should:

- Set in place and institutionalize mechanisms for effective coordination of urban agricultural activities.
- Reach an agreement with all stakeholders. These stakeholders should lead and coordinate the process.
- Institutionalise administrative procedures not only with a focus on the community level but with the community playing a leading role. Institutionalised procedures can help monitor negative and positive effects of urban agriculture with regard to social, economical and environmental conditions and help define responsible bodies to oversee the whole process. To be effective, these institutional procedures must build on and work through those informal institutions and networks that communities have created for themselves.
- Establish procedures to oversee the progress and foster issues regarding urban agriculture where the governments should adjudicate/supervise and the communities play the managerial role.

Urban agriculture is a reality throughout Zimbabwe. It is a positive social response to negative political, social and economic factors. Rather than work to 'uproot' urban agriculture, government should welcome its presence. Urban agriculture provides a ready opportunity for government and citizens to work together toward positive outcomes. Zimbabwe is sorely in need of such opportunities.

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Water losses and the political constraints to demand management: the case of the City of Mutare, Zimbabwe

Bekithemba GUMBO and Pieter VAN DER ZAAG

Department of Civil Engineering, University of Zimbabwe, PO Box MP 167, Harare, Zimbabwe
bgumbo@eng.uz.ac.zw

ABSTRACT
The question posed in this paper is: why is the concept of water demand management rarely implemented on the ground? To answer this question the paper presents data on the water supply situation in the city of Mutare, Zimbabwe. It describes Mutare's water infrastructure, the patterns of water use during the period 1980-2000; and our attempts to identify and quantify water losses in the system. Suggestions are made how these losses can be reduced, which would involve relatively modest resources. The question is then asked why these measures have not yet been taken. The paper contrasts this to the Pungwe scheme, a new water supply project of huge proportions which was conceived and implemented fairly quickly. The fact that water is a vital yet finite and fugitive resource explains why powerful water coalitions may emerge between engineers, financiers and politicians. It is the experience from Mutare and elsewhere that such coalitions tend to favour supply-side solutions to water scarcity. For effective adoption of water demand management it is essential to acknowledge this political dimension. As a strategy it is suggested that: (a) stakeholders should be better informed about alternative solutions to water problems; (b) a new generation of engineers trained in integrated water resources management is needed with the skills to carefully study the problem definition before rushing to solutions; and (c) financiers should be made aware of the relevance and economic rationale of demand management solutions.

Keywords: *demand management; supply management; unaccounted-for water; water loss.*

INTRODUCTION

"Water demand management" is a relatively new concept that features prominently in the Southern Africa Vision for Water, Life and the Environment in the 21st Century. The vision was adopted by the SADC Heads of State in Arusha early 2000 and presented at the 2nd World Water Forum in The Hague later that year. Water demand management is one of the new "darling" concepts in Integrated Water Resources Management: everybody is in favour of it, as it is difficult to oppose "demand responsive" approaches to water problems. The argument is sound and convincing: if there is shortage of water, don't limit the solution to supply options only (develop the next source of water), but also consider demand-side options, such as minimising water losses, and influencing demand to more desirable levels through structural (e.g. retrofitting of water appliances, recycling and re-use) and non-structural (e.g. awareness campaigns, restrictions on use, water tariffs) measures. Water demand management seeks to increase the efficiency of water use; and involves an approach to water resources development and management that critically analyses the water problem in a holistic manner. The efficient allocation and use of water requires the balancing of both the supply *and* the demand side of the water resources equation (OECD, 1989, Gleick, 1993; ISPAN, 1994; Winpenny, 1994; Gardner-Outlaw & Engelman, 1997; Pallett, 1997; Robinson, 1998; Foxon *et al.*, 2000).

In many situations the solution to the water problem will be increasing water availability through tapping new sources of water. In many rural areas in Southern Africa water use is undesirably low (Goldblatt *et al.*, 2000). If water demand management means influencing demand to reach more desirable water use patterns, here water availability has to be drastically increased. In some other situations, such as in many affluent neighbourhoods in Southern African cities, water use is considered too high. Here emerging water shortages may be met by among others, reducing water use and increasing efficiency (Macy, 1999). Nevertheless, in the face of a rapidly growing urban population, developing new sources of water will nearly always be part of solving urban water problems. What is therefore needed is a sound strategy for demand-cum-supply management (Savenije & van der Zaag, 2000).

So far the good intentions: we all embrace the concept of water demand management. However, it is seldom implemented in practice (Arlosoroff, 1998; Stiles, 1996). This paper attempts to find out why expensive supply-side solutions are often preferred, even in cases where these could have been usefully combined with, or preferably preceded by, demand responsive measures.

The paper uses the case of the City of Mutare, Zimbabwe as an example. It will be shown that local authorities still give priority to developing new water supplies if the opportunity arises and financing becomes available. Powerful coalitions between engineers, financiers and politicians may emerge around water that tend to favour supply-side solutions to water scarcity. For effective adoption and promotion of water demand management, it is essential to acknowledge this political dimension.

This paper is organised in five parts. First we briefly describe how our own thinking changed while studying the water situation in Mutare. The paper then describes Mutare's water infrastructure; the patterns of water use that were identified over the period 1980-2000; our attempt to quantify and pinpoint the water losses; and finally a brief description of events leading to the implementation of the Pungwe scheme.

1. Our quest of understanding Mutare's water problem

The drinking water situation in Mutare has undergone interesting developments over the period 1980-2000: from extreme water scarcity to plentiful water; from a relatively cheap supply infrastructure to one of Zimbabwe's most expensive water schemes. It is clear that water is a concern to this city. Our initial interest for studying the water supply system of Mutare was to study one aspect of water demand management, namely the impact of water tariffs on water consumption. Mutare seemed an ideal case, since its tariffs had an interesting sequence during 1990-2000, from low, to punitive (during the 1991/1992 drought), to relaxation, and to further increases (to fund the Pungwe pipeline, see further). After collecting some initial data, it emerged that the city seemed to experience relatively high water losses, and a large part of the treated water produced was not billed (some 40%). Since we had our reservations about tariffs as an important mechanism of demand management, we turned our attention towards identifying water losses and the level of unaccounted-for water in the system. We thought that measures that could decrease these losses would likely form a prominent part of any (short-term) water demand strategy. We clearly wanted to assist the City with identifying those measures (Gumbo and Van der Zaag, 2000).

An intensive data collection campaign was conducted during March-July 2001 with the assistance of four final year civil engineering students. The aim of the campaign was to collect data on water flows in the supply system, in order to identify where the water leakages occurred. This was seen as the first essential step towards identifying solutions. However, and to our disappointment, we failed to establish water balances in the various zones or sectors within the reticulation system, simply because all bulkmeters were not functioning. Our efforts to get some repaired (or replaced with brand new ones, which the city had in stock) were in vain: our research was based on a shoestring budget, and the City had run out of funds. After analysing all data collected, we could only corroborate our earlier findings, and conclude that as much as 50% of treated water produced was not billed, i.e. unaccounted for. We were not only disappointed, but also surprised: how could a city which had just completed a water scheme valued at around US$ 100 million not have a proper water monitoring and audit system in place, and unable to replace its bulkmeters? We wanted to understand why it seems easier to get a multi-million dollar water scheme in place than establishing the sources of water losses/unaccounted-for water in the system.

2. Mutare's water infrastructure

The City of Mutare is the fifth largest City in Zimbabwe. It is situated in the province of Manicaland, in Eastern Zimbabwe, of which it is the capital and administrative centre. The City lies a few kilometres from the border with Mozambique. The 1992 population census gave a total population 131,400 (69,600 in 1982). The existing main sources of water supply for Mutare are the Odzani

(Lake Alexander) and Smallbridge dams, located on the Odzani river, which is part of the Save catchment. The combined full supply capacity of the reservoirs is 21 Mm^3, with an estimated yield of 20 Mm^3/a. The third source is the Pungwe scheme (commissioned in March 2000), which has a capacity of 0.7 m^3/s (equivalent to 22 Mm^3/a; its secure yield (96%) being 16 Mm^3/a). From the Pungwe river water gravitates from the intake works through a 4.3 km tunnel and a 46 km pipeline to Odzani waterworks where it is treated and (sometimes) blended with water from the Odzani dams. The Odzani water treatment works has a capacity of producing 1.9 Mm^3/month (23 Mm^3/a). The treated water then gravitates to Christmas Pass reservoirs through three trunk mains of sizes 300 mm, 450 mm, and 750 mm extending for a distance of about 23 km, before distribution in Mutare. There are various abstraction points between Odzani waterworks and Christmas Pass. The 450 mm line is the oldest (1965) and a minimum flow is maintained in it because it serves 17 metered connections along its length to Christmas Pass. The consumers being served include the Rural District Council, mines, schools, small industries and farms. The 600 mm line (1976) is heavily corroded and cathodic protection has failed. The 750 mm line was recently commissioned as part of the Pungwe project.

The reticulation system within the city has been developed over a period of about 100 years. Fifteen clear water reservoirs are supplied by Christmas Pass reservoirs and have a combined capacity of 75,000 m^3, which is about one and half times the current consumption rate per day. Figure 1 shows a digital elevation model superimposed on the main distribution lines in the City.

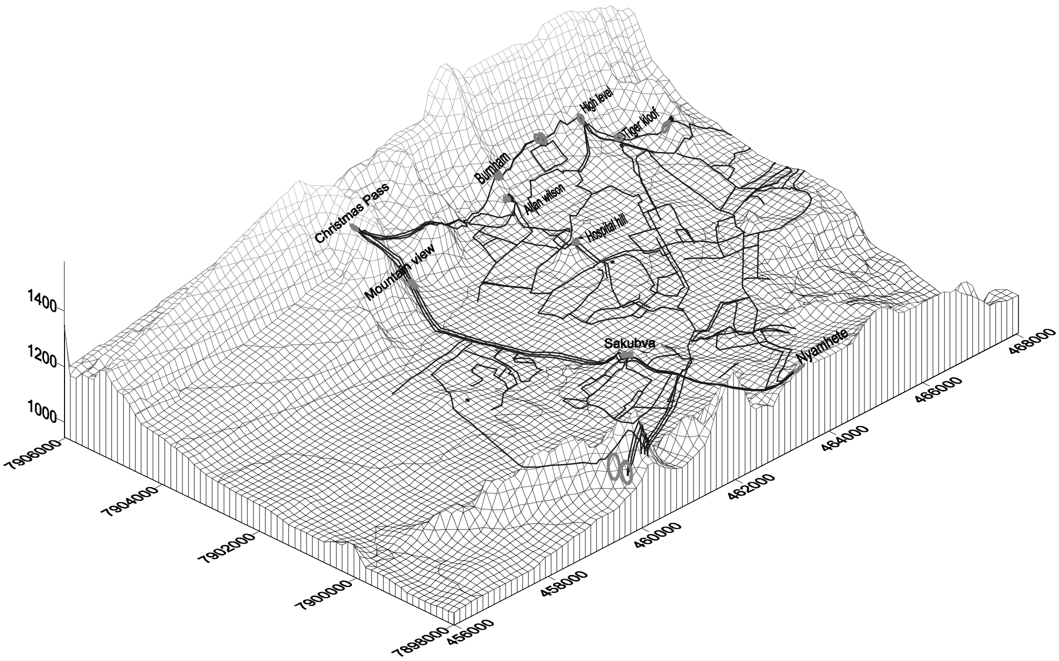

Figure 1: Digital elevation model showing the major water distribution mains from Christmas Pass reservoir to the City of Mutare

3. Patterns of water use in Mutare, 1980-2000 (Gumbo and Van der Zaag, 2000)

Over the 8 year period July 1983 to June 1991, water abstraction from Odzani water works grew by an average of 9,600 m^3/month. This growth is mainly explained by the increase in population (6.35 % per year over the period 1982-1992) and increase in economic activity (GDP in Zimbabwe grew some 3.6% per year over the period 1982-1991). Crude per capita water consumption (total treated water divided by the city population) averaged 8.9 m^3/capita/month over the period September 1983-September 1989, and tended to increase from around 7.5 to 10 m^3/capita/month. Water abstraction peaked during the period September 1990 and August 1991, at 1.50 Mm^3/month (or 18 Mm^3/a, close to the yield of the water supply sources then in place).

The disastrous drought of 1991/92 resulted in the combined storage to drop to an all time low of 375,000 m^3 in November 1992, an amount that would have been consumed within a week at pre-drought consumption levels (Figure 2)! This forced Mutare to adopt drastic water conservation measures. As a result water abstraction during January-December 1992 averaged only 0.47 Mm^3/month; i.e. less than one third of the previous year. From April 1992 to March 1993 gross per capita water consumption was only 3.0 m^3/capita/month. This significant reduction is explained by the massive campaigns, rationing, borehole drilling and tariff increases by the city council.

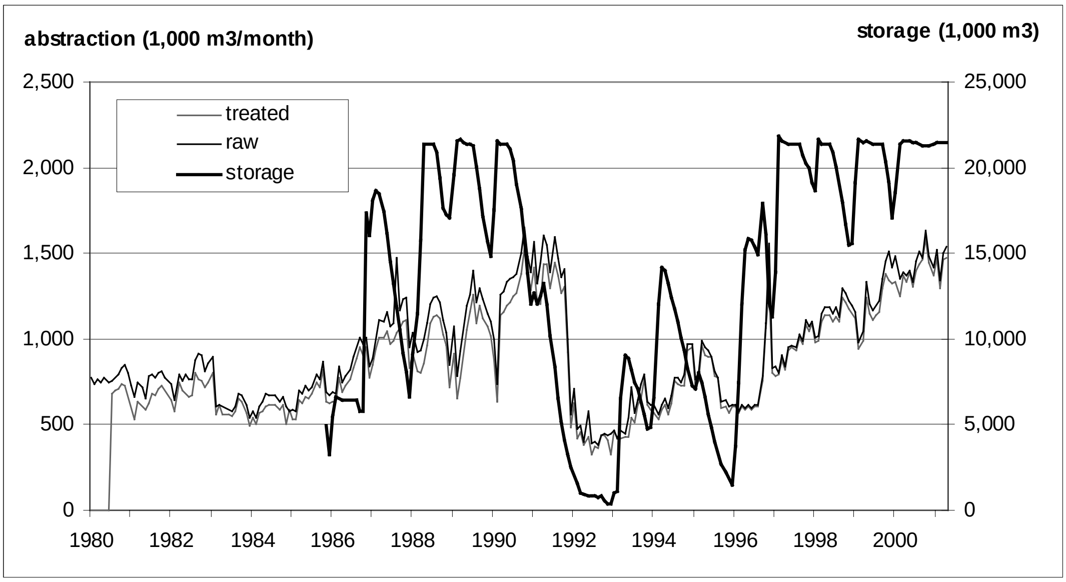

Figure 2: Water stored, raw water abstracted and treated water produced, Mutare; 1980-2001

After the drought Odzani and Smallbridge dams gradually filled up. Water abstraction began a steady increase again, at an average rate of 9,100 m^3/month over the period 1992-1999. Over the period September 1993-September 1999, gross per capita water consumption averaged 5.5 m^3/capita/month. The city population increased from 131,000 in 1992 to some 175,000 at the end of 1999. Only in 2000 did the water abstraction reach the levels of 1990/91 (Figure 2).

Half of all water is used in the so-called high-density areas, such as Chikanga, Dangamvura, and Sakubva, and the balance in the other parts of the city. Domestic water use accounts for up to 70% of total water supplied; the remainder is used by industries and institutional and commercial users.

Mutare uses an increasing block tariff system. This is believed to be a pricing system that combines fairness (through cross-subsidies) with a clear signal to consumers to rationalise water use, and minimise those uses that are deemed less essential. Mutare also charges a fixed rate per connection per month, which somehow compromises the fairness of the system. Figure 3 shows an interesting sequence of tariffs for domestic water during the period 1991-1996: from a punitive tariff (1991-1992) during a period of extreme water shortage; to a 'normal' tariff (1993-1995), which saw a significant price decrease; to substantial tariff increases (from September 1995 onward). Water tariffs were subsequently further increased due to the new Pungwe project. One of the conditions of the institutions that provided the loans for this project was that from the start of the construction works Mutare had to institute tariffs that would allow repayment of the loans (Herald, 12/07/96; Financial Gazette, 18/07/96).

On the basis of these data, and with a view to better understand which factors determine consumption levels, an attempt was made to model water consumption. This, it was believed, was important to establish the relative importance of water tariffs in water demand management strategies. The following conclusions were drawn:

1. The threefold decrease in water consumption during the drought of 1992 was achieved through a combination of measures: a punitive water tariff (in real terms the tariff has since not been as high), bans on certain water uses, rationing, borehole drilling and public awareness campaigns.

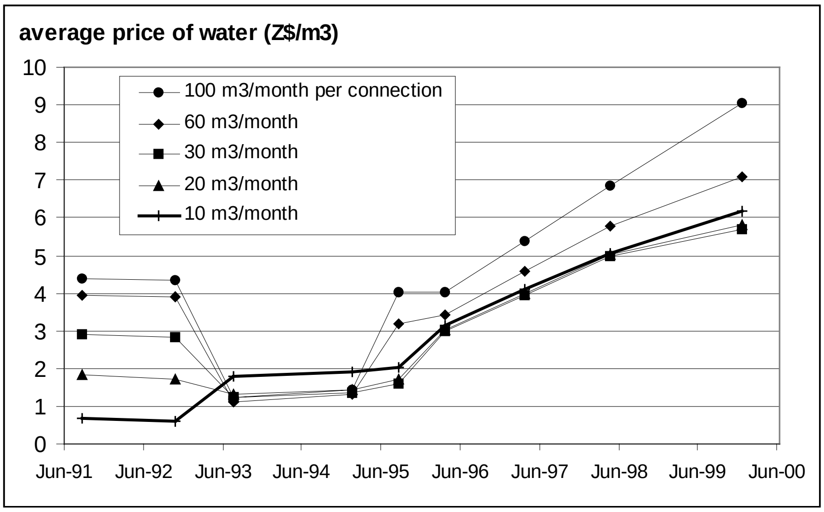

Figure 3: Average price of domestic water at different consumption levels, Mutare; 1991-2000

2. Water use 'bounced back' in four years to levels that must be considered 'normal'. However, crude per capita consumption remained some 30% lower than during the pre-drought period, and never exceeded 7 m^3 per capita per month.
3. The model developed took into account population growth, economic growth, rainfall, and a 'bounce-back' factor after water restrictions during the 1984 and 1992 droughts, were relaxed. These factors could explain as much as 70% of actual water use. Including water tariffs into the model did, however, not improve model behaviour.

These preliminary results indicated that water tariffs may have a limited scope as a water demand management tool.

4. Unaccounted-for water in Mutare

Another preliminary conclusion was that unaccounted-for-water is unacceptably high in Mutare; and that tackling this problem would probably be the best way of reducing the City's demand for water in the short-term. It was recommended to identify the main sources of losses/unaccounted-for water, and those cheapest to avoid. Therefore a measurement and data collection campaign was conducted (March-July 2001). Due to lack of complete data series and non-functioning measuring devices, the findings were inconclusive in many respects, but included the following:

- The average gross loss (the unaccounted-for water) for the whole network i.e. from Odzani to the consumer was estimated at 52% of the water produced at Odzani, ranging from 45-61% (Figure 4).
- During treatment of raw water some 4.5% of water is lost, which is considered acceptable.
- In June 2001, 1.5 Mm^3/month of treated water was conveyed from Odzani to Christmas Pass (23 km); 50% of the flow was carried by the new 750 mm pipe (constructed in 1997), 15% by the 600 mm pipe (1976), and 35% by the oldest pipe (450 mm; 1965). The large pipe did not experience measurable leakages. The losses in the 600 mm pipe could not be ascertained because of inconsistent data. The oldest pipe lost 0.12 Mm^3/month (8% of total treated water produced). Losses of a similar magnitude are likely in the 600 mm pipe, given its heavily corroded state. As much as a third of all unaccounted-for water may be caused by both pipes.
- Water losses within the reticulation network could not be ascertained, simply because none of the bulkmeters (installed at the inlets and outlets of the 15 reservoirs) were functioning. Therefore no water balances could be made for specific zones/sectors.
- Many industries have non-functioning water meters and are billed nominal quantities. An example is Mutare Board and Paper, one of the biggest water users in the city, which is believed to use 5 to10% of all treated water (this excludes water pumped from its own private boreholes). Five of its eight water meters are not working. The quantities billed are believed to be a fraction of actual water consumption, but this fraction could not be ascertained.

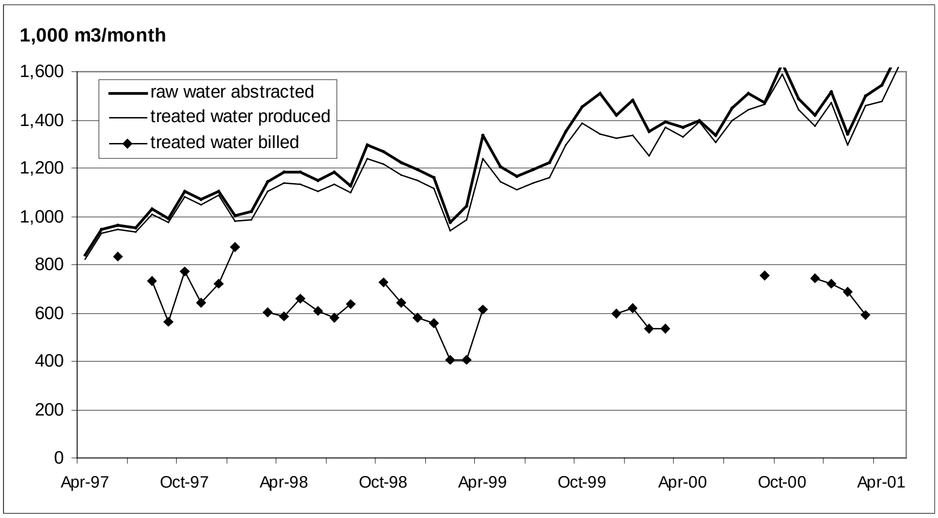

Figure 4: Raw water abstracted, treated water produced and water billed, Mutare, 1997-2001

- All households in Mutare are metered, except for one part of Sakubva. This part of Sakubva has communal water and ablution facilities servicing 1,550 housing units with a population of at least 20,000 people. Many taps have been vandalised and water flows continuously. It has not been possible to estimate the water losses involved.
- Because of the undulating terrain of Mutare, water pressures vary greatly. Certain areas experience high static pressures such as Fairbridge, Chikanga, the heavy industrial areas and Dangamvura. The frequency of pipe bursts appears to be correlated with high pressure areas.
- During the period 17 January-31 October 2000 the City Council recorded 691 reports of pipe bursts (2.4 bursts per day on average). Of these, 251 (36%) occurred in Dangamvura high-density area (with an estimated 50,000 residents). Council officials attribute the high frequency of pipe bursts to substandard materials used when Dangamvura's reticulation system was built.

On the basis of the above findings, the following recommendations can be formulated:

1. The city is urged to establish a proper monitoring and water audit system that would allow water flows to be known, providing important feedback about the performance of the water supply system. This would among others involve the repair of all bulk meters and their regular readings. The water readers could be better placed in the Engineering department, rather than in the Treasury department. The engineer in charge of water supply would thus have direct access to data on billed water. Any inconsistency in data could timeously be identified, allowing the speedy the identification of any undetected leakages. A proper data information system is essential and can be used to generate data required for billing by the Treasury department.
2. All non-functioning consumer water meters should be repaired, starting with the industries.
3. In certain sectors pressure zoning and pressure management should be improved.
4. In certain areas, such as parts of Dangamvura, the reticulation system needs to be overhauled.
5. The engineering department should be allowed to receive or retain a certain specified part of the water revenues collected. As it is at present, the department has insufficient funds to even carry out the barest minimum of maintenance. As one well-known Harare engineer once put it: *"You can milk the cow, no problem; but never forget to feed it."*
6. Finally, the deep-seated causes of the water problems in Sakubva should be resolved. A truly participatory process should be adopted in order to identify causes and formulate measures.

The question is not only what the City should do to diminish water losses/unaccounted-for water and increase revenue, but also why the Council itself has so far not taken the initiative to implement measures. This seems inconsistent with the massive investment the Council has made for the supply system in the form of the US$ 100 million Pungwe pipeline. The first four recommendations would involve only a fraction of the Pungwe investment. Why is a city willing to invest millions and not thousands?

5. The Pungwe scheme

This section provides a brief account of how the Pungwe project was started. This helps to understand the dynamics involved when investment decisions related to water are taken, and also illustrates how easily demand management options may lose priority in this decision-making process.

The traumatic experience of the 1992 water crisis fuelled local politicians, residents and the Department of Water Development to search for a new additional source of water for Mutare. There was consensus that the capacity of the existing water system (20 Mm^3/a) had to be doubled to cater for the city's need up to the year 2010, when the population was projected to have surged to 300,000 people. The water requirement of 40 Mm^3/a of raw water for 300,000 residents was based on the unrestricted water consumption in the period prior to the great drought of 1992.

No questions were raised regarding the demand-side of Mutare's water problems. If the city's water need would be based on, say, half the unrestricted demand (still 50% more than the consumption during the year of the great drought), the existing system would suffice until the year 2010. If all efforts would be directed to reduce system losses/unaccounted-for water, consumption could either increase to more acceptable levels, or new supplies could be postponed even further. Was it known how much the system losses were? These questions were ignored. The city firmly believed that with more water available, and given its strategic location along the Beira corridor, between the Indian Ocean and Harare, the town would be ready for a "business boom" (Sunday Mail, 21/7/96). The quest for doubling Mutare's water supply was on.

Three supply-side options were considered during 1994-95. The first was a relatively small dam on the Odzani River, augmenting the storage capacity of the two existing dams on the same river. This option was the cheapest in terms of capital investment (US$ 5 million) but would also yield relatively little water (13 Mm^3/a). The second option was taking water from the just completed Osborne dam (storage capacity 400 Mm^3) on the Odzi river, 30 km north-west of Mutare. The Department of Water Development, which owns the dam, had reserved 28 Mm^3/a for Mutare and had already constructed the intake works for a 28 km pipeline to Mutare. This Osborne-Mutare pipeline-cum-treatment works project was estimated to cost US$ 37 million, of which 5% had already been spent. The technical advantages of this options were: (1) it would yield sufficient water to cater for the needs of Mutare for the next two decades, (2) this option could be implemented fast, since the dam had already been built, as well as the intake works. The option also had two disadvantages: (1) raw water would have to be pumped, whereas the current sources allow water to gravitate to the water treatment works; (2) treatment costs would increase since Osborne water is relatively turbid compared to Odzani water. So this option would involve relatively high recurrent operational costs.

The third and preferred option involved taking water from the Pungwe river which is not part of the Save catchment. The advantages of this option were:

1. the water would gravitate through a 4 km tunnel and a 46 km pipeline to the existing treatment works at Odzani, from where it would further gravitate to the city; this option would therefore not require any pumping; since the source is perennial, no storage works were required either;
2. the water drawn from the Pungwe would be pure, hardly requiring any treatment; and
3. the pipeline would be owned by the city.

The disadvantages were:

1. its secure yield (16 Mm^3/a) fell short in providing a supply solution for the coming 15 years;
2. it would be expensive to build (US$ 100 million; Financial Gazette, 22/02/96; Herald 20/05/96); much more than the next expensive option, which would have a much higher yield;
3. it could create problems with Mozambique, as Beira entirely depends on Pungwe water; and
4. it could negatively impact on the pristine ecology of the Pungwe catchment.

In arriving at its decision, the City Council appeared to have used two major criteria. The first was that it wanted to own the new water system in order to be fully in charge, and not depend on central government. The second was obvious, namely that it would prefer the option that was cheapest to the city. The Pungwe alternative, while by far the most expensive in terms of investment, had the lowest running cost. If the city would be able to access government loans on the usual local authority borrowing terms, the interest rate would be lower than the annual inflation rate (~20%) (Zimconsult, 1996). This meant that the best option would always be that option with the lowest recurrent operational costs, whatever the initial investment. The Pungwe alternative was the only one scoring positive on both criteria.

The City Council now had to solve a number of obstacles to get the pipeline constructed. First, the Department of Water Development was in favour of the Osborne option. It argued that the Pungwe scheme was too expensive and would yield little water (Financial Gazette, 25/4/96; Manica Post, 7/6/96). Since Mutare would require the department's approval for its preferred alternative, it had to make it change its mind. Second, the Council had to present the preferred option to the Mutareans as the best, if not the only way of solving Mutare's water woes, such that the residents would forget to ask difficult questions, such as how much the Pungwe water would cost. Third, the Council would have to overcome Mozambique's opposition against the Pungwe scheme. And finally, it had to find a suitable financing package.

The City Council managed to overcome these odds within a period of 18 months, through establishing a fruitful relationship with a Swedish construction firm (which backed up the City's preferred option with engineering facts, and mobilised support from Sida, the Swedish International Development Agency), and by carefully exploiting political opportunities within a faction-ridden Manicaland province of the ruling party. But the major feat was that the council managed to portray the Pungwe project as providing purity (pristine water), security (no more shortages) and prosperity (more business) to its residents, all in one (Manica Post, 3/11/95). These powerful values became synonymous with the Pungwe, and convinced most people. Few still wanted to look into the detailed merits and demerits of this option. Once popular support was achieved, the vying politicians could do little else than follow suit.

One outstanding issue was that a declaration of no objection from the government of Mozambique was required before the project could go ahead. This was a condition set by donors, but also seemed reasonable. The Pungwe River, shared between Zimbabwe and Mozambique, is the only fresh water source of the city of Beira (500,000 inhabitants). Tedious negotiations at government level finally resulted in an agreement whereby Mutare was allowed to take a maximum of 700 l/s, provided that it would always leave a flow of 500 l/s in the river at the point of abstraction. Engineers subsequently translated this agreement into a specific design of the river off-take. Construction of the Pungwe pipeline started in December 1996, was completed in December 1999 and officially opened by President Mugabe in March 2000.

A small but influential group of actors managed to get a project off the ground that some believed was the least feasible of several options to solving Mutare's water crisis. The group managed to enrol highly placed ruling party leaders, who for once set aside their differences. They also enrolled a Swedish engineering company and international and local financing institutions, and overcame initial opposition from the Department of Water Development. Around the Pungwe a strong network formed. The network effectively dealt with voices of dissent. Mutare residents, blinded by the Pungwe symbol, were made to forget the impending tariff increases. The Mozambican government reluctantly accepted the project. Environmentalists were painted as a "clique of very few individuals" (Manica Post, 7/6/96). And small-scale farmers in Honde Valley, who opposed the scheme because they feared that Mutare's abstraction would dry up their part of the Pungwe river, were threatened with eviction (Financial Gazette, 21/4/95).

By the year 2000 the main proponents of the pipeline were pleased. The Swedish engineering firm could add another engineering miracle to its portfolio (constructed in time, within budget, with minimum environmental impact). Standard Bank was proud to have engineered with Sida an innovative financing modality whereby US$ 5 million of aid money generated US$ 45 million of local financing from the private sector (African Business, July/August 1999). (In addition a Nordic financier provided the foreign component (US$ 50 million) as a loan to the Zimbabwe government.)

The City Council was also pleased as it managed to get the option it wanted. It now owned a pipeline that produced water at very low recurrent cost, while it did not worry too much about the loan repayments, the interest rates charged being less than the inflation rate. After the inauguration of the pipeline the supply of water from the old source of water was closed, and only Pungwe water was used, which hardly required treatment and saved substantial amounts of money. Water consumption could now continue to grow. In October 2000, raw water abstraction surpassed the all-time record of January 1991, namely 1.6 Mm^3/month. The council treasurer was happy, because more water delivered meant more revenue with which to stopgap the City's budget.

The only problem was that the pipe network did not co-operate: pipes kept on leaking and bursting, and more water meters mysteriously got stuck. It was now pure Pungwe water that disappeared. Few people wanted to know that half of the precious water remained unaccounted for.

DISCUSSION

The Mutare case shows what forces are at play when crucial decisions concerning water are made. It is clear that these forces did not embrace concepts related to demand management. If we want to further promote a balanced demand-cum-supply management of water resources, we have to acknowledge these forces. Why are such forces strong in water resources management, and why do they often point in a direction opposite to demand-oriented measures? Why, for example, didn't a strong coalition emerge to address the current levels of unaccounted-for water?

The answer to these questions must be related to some special attributes of water. Since water is *finite*, different uses and users compete for it, and it easily obtains a value. Since water is a *vital*, life giving resource without which we cannot survive, it may obtain an incalculable value, even a political one. Controlling water may thus become a political rallying point. Since water is *fugitive*, it often requires sophisticated and costly engineering infrastructure to harness it.

Taken together these three fundamental attributes of water may facilitate the emergence of powerful coalitions between engineers, financiers and politicians. Engineering firms will be more than willing to apply their knowledge and skills to ambitious water projects, and they may tend to favour the larger supply-oriented projects as it would generate more work. To financiers, a monopolistic water supply system for a city is normally an attractive investment, since the city's residents will always need water. Politicians, finally, are likely to initiate water projects as this will portray them as the provider of a life-giving resource that enhances health, security and prosperity.

Demand-oriented projects, however, are not necessarily less challenging than supply-oriented projects. Interventions such as monitoring systems, leakage control, replacement of old pipes, retrofitting of water appliances in households, and awareness campaigns do require political commitment, engineering inputs as well as finance, but these interventions cannot easily be 'boxed' into discrete time- and space-bound projects. Demand-oriented solutions may require many small engineering inputs, many relatively small financing deals, and a continued commitment from politicians. Worse still, politicians will have to engage with their constituencies in exploring options for behavioural change. Instead of posing as the great provider, politicians will have to make their electorate aware of a problem that the voters themselves will have to (partially) solve.

The above makes it plausible why the worlds of finance and engineering tend to ignore demand-side solutions, and often convince local politicians of the superiority of grand supply solutions. In the process, issues of maintenance and monitoring receive cosmetic attention at best.

Promoting more balanced and holistic demand-cum-supply management therefore requires, first and foremost, information campaigns about the benefits of demand-oriented solutions targeting ordinary residents. Better informed, residents are less likely to be blinded by grand projects, but may instead pressurise politicians for detailed information on the merits and demerits of the options available. A second track would be to influence engineers. A new generation of engineers trained in integrated water resources management is needed who have the skills and the holistic vision to carefully study the problem definition before rushing to provide solutions. A third track should target financiers, and convince them of the economic rationale of looking beyond supply solutions.

Water demand management remains an idealistic "darling" concept. If we are serious in implementing water demand management we have to acknowledge that water projects often have a strong political dimension, which may stand in the way of finding and implementing the most efficient solution. Implementing sound demand-cum-supply management requires the active participation of all stakeholders, including academics.

ACKNOWLEDGEMENTS

This research was made possible through grants from the University of Zimbabwe Research Board/SAREC to the projects "Managing Mutare's domestic water use: minimising losses" (3YRR10/00034) and "Scope for demand management of domestic water in urban centres of Zimbabwe" (3Y12). We thank Eng. D. Nyatoti and Eng. G. Muskwe, City of Mutare, for their kind assistance; F. Matahwa, E. Makita, E. Mukaratirwa and C. Nhawu, for collecting many data; and T. Chikoto and N. Munyamba for digitising maps and setting up the GIS database. Part of the research was conducted in collaboration with the project "Security, ecology, community: contesting the "water wars" hypothesis in Southern Africa", funded by the Water Research Commission of South Africa, and coordinated by the University of the Western Cape, South Africa.

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Coupling of digital elevation model and rainfall runoff model in storm drainage network design.

Bekithemba GUMBO[1], Nelson MUNYAMBA[2], George SITHOLE[2] and Hubert H.G. SAVENIJE[3]

[1]University of Zimbabwe, Department of Civil Engineering, PO Box MP 167, Mount Pleasant, Harare, Zimbabwe
[2]University of Zimbabwe, Department of Geo-informatics and Surveying
[3]IHE-Delft, 2601 DA, Delft, The Netherlands

[1] gumbo@ihe.nl

ABSTRACT

Often planners and engineers are faced with various options and questions in storm drainage network design e.g. flow pattern, direction, runoff quantity and therefore size of drain, or scenario after a road, airfield or building has been constructed. In most instances planning without drainage in mind has caused failure or extensive damage to property including the storm water drains which channel the water away. With the advent of various modelling and GIS tools this problem can be averted. The University of Zimbabwe's (UZ) main campus had its storm drainage network reconstructed at a cost of about US$100 000, because of persistent flooding. This paper describes a method of assessing the effectiveness of storm drainage networks by combining a Digital Elevation Model (DEM) with a rainfall runoff model based on the Soil Conservation Service South African manual (SCS-SA). The UZ campus was used as the test site. The DEM was generated from aerial photographs and the data imported into ArcView. The 3.0 km^2 basin was then delineated into sub-catchments using ArcView Hydro extension tools. The land use, watershed and soil map of the UZ were merged in ArcView and initial Curve Numbers (CN) assigned. Using three years of daily rainfall data, runoff and peak flows were calculated for each sub-catchment. By overlaying the natural flow lines derived from the DEM with the reconstructed physical drains a comparison of the flow direction and the orientation of the drains was achieved. Peak flows where calculated for each delineated watershed and the results used to check the adequacy of the trapezoidal concrete lined drains. A combination of a DEM and rainfall-runoff model within a GIS platform proves to be useful in estimating runoff on partly urbanised watersheds and in determining the size and orientation of storm drains. It is particularly useful for new areas where development is being contemplated.

Keywords: *storm drainage; surface runoff; Digital Elevation Model; Rainfall-Runoff Model; SCS-SA method; GIS; ArcView*

INTRODUCTION

Problems with management of urban rainfall have their roots in concentration of population on a relatively small area. In order to make living and transportation possible large impervious areas are constructed. This results in a change of hydrological cycle. Infiltration and groundwater recharge decreases, pattern of surface and river runoff is changed imposing high peak flows, large runoff volumes and increased transport of pollutants and sediment from urban areas. Thus the city influences the runoff pattern and the state of the ecological systems not only within the city area but also in and around a whole river system downstream. Stormwater management therefore requires integrated planning considering the total water cycle in the water basin (Niemczynowicz, 1997; Malmquist & Bennerstedt, 1997).

Geographic Information Systems (GIS) in combination with appropriate rainfall -runoff models provide ideal tools for the analysis and management of urban stormwater (Demayo & Steel, 1996; Bellal *et al*, 1996, Miloradov & Marjanovic, 1991).

Inadequate information about drainage patterns is the most common cause of failure of storm water drains, roads, airfields and built up structures. Therefore drainage patterns are an important consideration in planning, designing, and building roads, airfields, storm water drains and other structures (US Army Corps Technical Manual, 1998). Zimbabwe's Ministry of Transport annual report (MoT, 1985) states that, 40% of cases of road failures are attributed to failure of storm water drains. To minimise annual maintenance, drainage patterns of an area concerned must be known and modelled i.e. estimation of runoff quantity and its flow direction. This paper describes the application of a DEM coupled with a rainfall runoff model in a GIS environment in estimating storm water generated and, flow direction in drainage network design.

DESCRIPTION OF STUDY AREA

The University of Zimbabwe's (UZ) main campus had its storm drainage network reconstructed in year 2000 at a cost of about US$100 000, because of persistent flooding. The University was therefore an ideal site for analysis and testing of an integrated run-off model in a GIS environment. Some salient points about the University of Zimbabwe campus are presented below:

- The University of Zimbabwe campus (Longitude 31° E, Latitude 18° S) covers an area of about 3.0 km^2 (Figure 1)
- 50-60 % consists of impermeable surfaces in form of roads, buildings, footpaths and sports facilities
- The terrain is generally flat. Mean elevation is about 1510m above mean sea level
- Mount Pleasant where the University campus is located forms a water divide, and one of the main rivers draining the city of Harare (Marimba river) originates here
- Two weather stations are available where daily rainfall is measured. Highest rainfall is recorded between December and February. Figure 2 shows the monthly rainfall recorded at the two stations (Crop Science Department and Geography Department) for the years 1996. 1997 and 1998.
- Mean maximum daily temperature is 27^{o}C

STORM DRAINAGE NETWORK DESIGN IN ZIMBABWE

Storm drainage coverage in Zimbabwe is closely linked to road network development and maintenance. The target is usually 60% coverage in most high-density suburbs (Township roads and storm-water drainage Manual 6, 1990; MoLGH, 1981). Other storm drainage design manuals used are issued under the auspices of the Ministry of Transport (MoT, 1985).

The design approach based on the rational formula is frequently used for areas less than 2 km^2. The recommended runoff coefficients for use with the rational formula are: Grassed areas and parks 0.3; bare soil 0.35, low density residential 0.4; medium density development 0.6; high-density development 0.85; fully paved areas and road reserves 0.95. The design flood recurrence interval for residential areas is 1-5 years. The Department of Meteorological Services, Intensity-frequency-duration curves are used for the design (Climate Handbook of Zimbabwe, 1980). The common shapes of the drains are the wide V drains, trapezoidal (trap) drains and storm water pipes. Minimum size for storm-water pipes should be 450mm diameter regardless of capacity. Manhole maximum spacing is 200 m. Scour velocities for various materials in m/s: fine sand 0.6; loam 0.9; clay 1.2; gravel 1.5; soft shale or decomposed rock 1.8; hard shale or soft rock 2.4; hard rock 4.5.

DIGITAL ELEVATION MODEL

There are various ways of representing continuous surfaces in digital form using a finite amount of computer memory capacity. For the purposes of GIS models, Digital Elevation Models (DEM) are the most convenient means for representing the earth's surface.

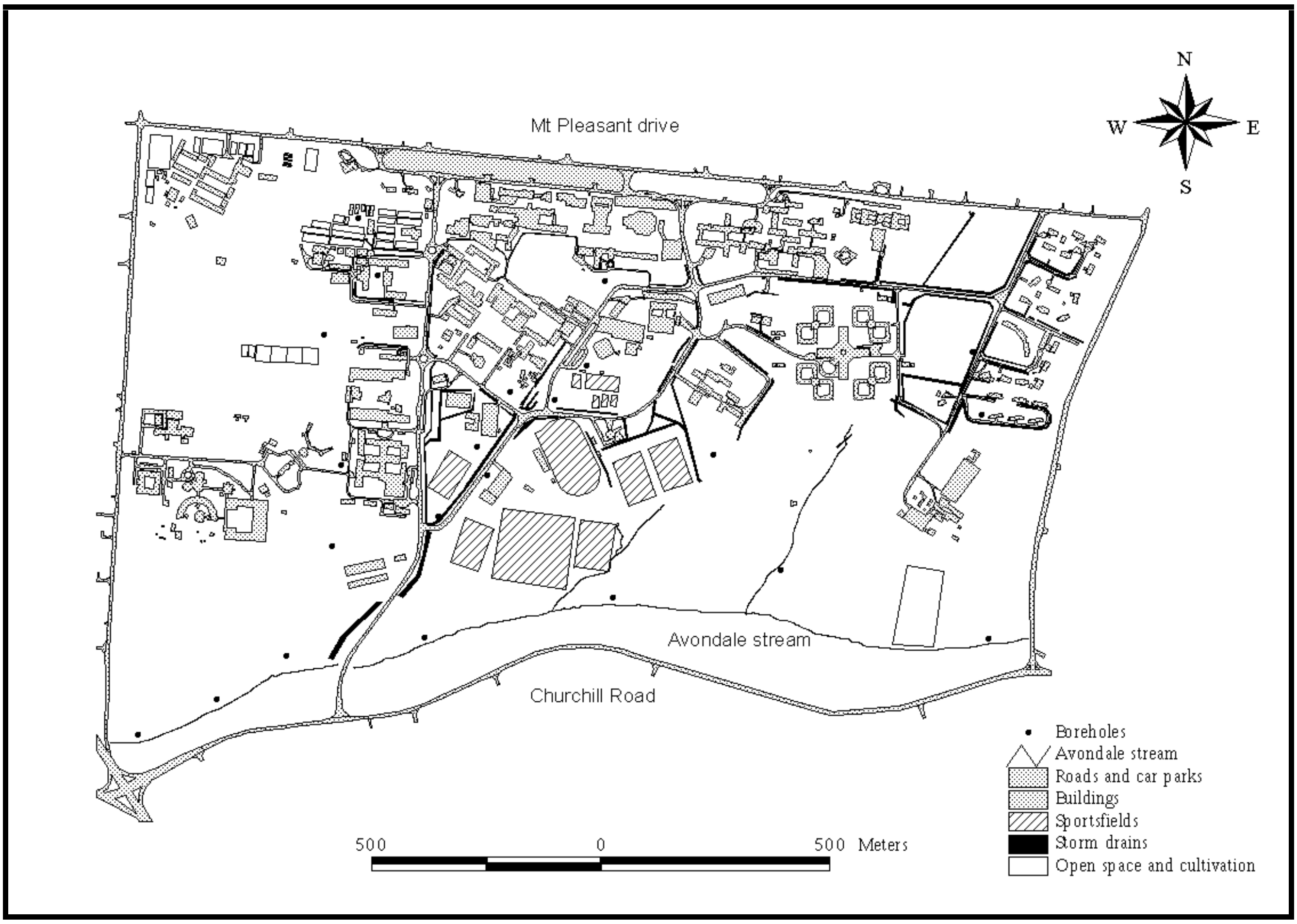
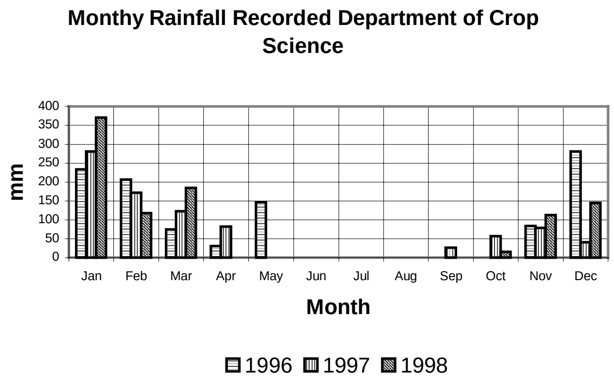


Figure 1 Layout and land-use map of the University of Zimbabwe campus



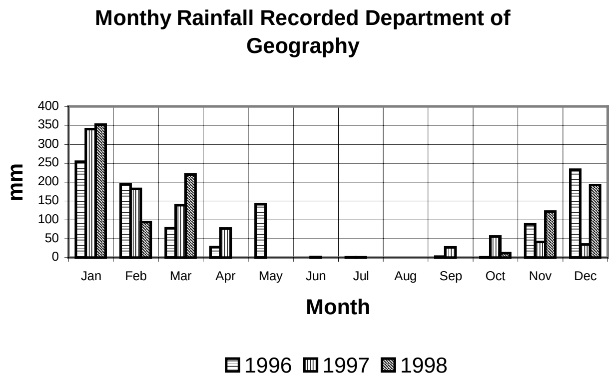


Figure 2 Variation of monthly rainfall recorded at the two stations within the University of Zimbabwe Campus (1996, 1997 and 1998)

DEM's are a collection of geo-referenced elevation points arranged in a regular or irregular grid. Among other things, certain software can display DEM's to show the terrain surface in three dimensions and from a choice of viewpoints (Petrie, 1990).

A regular grid has points equally spaced regardless of the shape of the terrain. An irregular grid samples extra points or a larger percentage of points in areas of increased relief variation, such as along ridges, mountains, and valleys. The more densely the elevations are recorded, the better the model will depict the real surface. More points, however, require more work and create more demand for data storage, both of which contribute to higher cost (Stefan, 1996).

Data used for generating DEMs is normally obtained by field surveys, GPS surveys, Photogrammetry, Satellite Remote Sensing, Airborne Laser Altimetry and digitising of existing maps and plans. However, in most cases elevations are interpolated from digitised contour lines on pre-existing maps. Typically the contour lines on these maps are created from aerial photographs using photogrammetry. In recent years it has become common to create DEMs directly from the photographs, and later derive contours from the DEM if desired (Francisco, 1996). The DEM described in this paper was generated from aerial photographs using Adam 3DD software (Adam 3DD, 1995).

The accuracy in environmental modelling (e.g. watershed delineation) depends very much on how "truthful" the DEM is to the actual terrain surface. The representativeness of a DEM depends on the quality of data (e.g. density, distribution and accuracy), and the method chosen to interpolate this limited number of data points.

SURFACE RUNOFF AND RAINFALL-RUNOFF MODELS

Surface runoff refers to the loss of water from an area by flow over the land surface. It occurs when rain falls with intensity greater than the rate at which it is able to infiltrate the soil.

Runoff flow is composed of two main elements: base flow, which has its origin in ground water, and surface runoff, which is the accumulation of rainfall that drains to the stream. The characteristics of a watershed that affect the base flow and runoff include, geology, soil type, vegetation cover, mean precipitation, drainage area and antecedent moisture condition (Bellal *et al*, 1996; Bouwer, 1986; Debource *et al*, 1994). The watershed characteristics are considered in determining the Curve Number (CN) index, which expresses a catchment's response to a storm event (USDoA, 1986).

There are generalised computer models of watershed hydrology that are able to compute sequences of daily or monthly stream-flows for a given precipitation unit. The advantage of these systems is the accuracy of its predictions. Their major disadvantage is that they require considerable expertise, time and effort to be used effectively. In between the extremes there are methods like the Soil Conservation Service (SCS) curve number method that are relatively easy to use and yield adequate results (USDoA, 1986; Schulze *et al*, 1992).

An adaptation to the SCS curve number method provides the adequate balance between ease of use and accuracy, but it is necessary to assure that the information required is readily available. The use of GIS becomes important so as to provide accurate spatial information required to apply this method (Bellall *et al*, 1996).

THE SCS CURVE NUMBER METHOD

The standard SCS curve number method is based on the following relationship between rainfall depth, P in millimetres, and runoff depth, Q in millimetres (USDoA, 1986; Schulze *et al*, 1992):

$$Q = \begin{cases} \dfrac{(P-0.1S)^2}{P+0.9S} & P > 0.1S \\ 0 & P \le 0.1S \end{cases} \qquad \text{Where} \qquad S = \frac{25400}{CN} - 254 \qquad \textbf{(1)}$$

To obtain volumes, P and Q (in millimetres) must be multiplied by the basin area. The potential maximum retention, S in millimetres, represents an upper limit of the amount of water that can be abstracted by the watershed through surface storage, infiltration, and other hydrologic abstractions. For convenience, S is expressed in terms of a curve number, CN, which is a dimensionless watershed parameter ranging from 0 to 100. A CN of 100 represents a limiting condition of a perfectly impermeable watershed with zero retention and thus all the rainfall becoming runoff. A CN of zero conceptually represents the other extreme, with the watershed abstracting all rainfall with no runoff regardless of the rainfall amount.

The watershed parameter CN can be determined from empirical information. The SCS has developed Tables of initial curve number (CN_i) values as a function of the watershed soil type, land cover/use/condition. These are listed in the SCS-SA User Manual (Schulze *et al*, 1996)

The hydrologic soil groups refer to the standard SCS soil classification procedures, where classification A refers to sand and aggregated silts with high infiltration rates, and goes to classification D, that corresponds to soils that swell significantly when wet and have low infiltration rates. Table 1 summarises the characteristics of the hydrologic soil groupings (Schulze *et al*, 1996).

Table 1 Summary of the characteristics of the hydrologic soil groupings

Soil Group	Storm–flow Potential	Final Infiltration Rate mm/hr	Permeability Rate mm/hr
A	Low	25	> 7.6
B	Moderately Low	13	3.8 to 7.6
C	Moderately High	6	1.3 to 3.8
D	High	3	< 1.3

N.B.

- In Southern Africa intermediate soils exist (A/B, B/C, C/D)
- Final infiltration and permeability rates given above refer to saturated soil
- Final infiltration rates refer to soils with a short grass cover
- Infiltration/percolation tests, following standard procedures (Bouwer, 1986), may be conducted at a number of sites in the watershed to assist in soil grouping
- Where typically deep soils are in shallow phase, for example on steep slopes, they should be downgraded one group (e.g. B becomes B/C)

For a watershed with sub-areas of different soil types and land cover, a composite curve number CN_c is determined by weighting the CN's for the different sub-areas in proportion to the land area associated with each (A_n).

$$CN_c = CN_1(A_1/A_{total}) + CN_2(A_2/A_{total}) + ... + CN_n(A_n/A_{total}) \quad \textbf{(2)}$$

Although the method was developed to determine runoff from single storm events, it might be also appropriate to approximate monthly values. Observations of gauged data indicate that the runoff volume associated with a particular precipitation depth tends to vary greatly between storm events. The CN method estimates the mean runoff associated with a particular precipitation depth and may be significantly in error for a particular rainfall event. However, Goulding, (1997) notes that the fit of measured data to the CN relationship improves with aggregation, such that estimated daily runoff from daily rainfall has less scatter than for daily values.

The CN_i value can be adjusted for near saturated and dry watersheds as shown below:

$$CN_{wet} = \frac{CN_i}{0.4036 + 0.059CN_i} \quad \textbf{(3)} \qquad CN_{dry} = \frac{CN_i}{2.334 - 0.01334CN_i} \quad \textbf{(4)}$$

DETERMINING THE TIME-OF-CONCENTRATION

To determine how the runoff is distributed over time we must introduce a time-dependent factor. The time-of-concentration (T_c), is used in the SCS methods. The T_c is most often defined as the time required for a particle of water to travel from the most hydrological remote point in the watershed to the point of collection. There are several methods available for calculating T_c, one of which is the SCS Lag Method:

$$L = \frac{l^{0.8}(S' + 25.4)^{0.7}}{7069 y^{0.5}} \qquad \textbf{(5)}$$

L = catchment Lag time (min)
l = hydraulic length of catchment along the main channel (m)
y = average basin slope
S' = obtained from Equation 1 with CN adjusted for antecedent soil moisture

$$T_c = \frac{L}{0.6} \qquad \textbf{(6)}$$

ESTIMATION OF PEAK DISCHARGE

SCS calculation for peak discharge is based on the triangular unit hydrograph concept. This unit hydrograph represents the temporal distribution of storm-flow for an incremental unit depth of storm-flow, *d*Q occurring in unit duration of time, *d*D.
Peak discharge for an increment of time *d*D is:

$$dq_p = \frac{0.2083 \times A \times dQ}{\frac{dD}{2} + L} \qquad \textbf{(7)}$$

where dq = peak discharge of incremental unit hydrograph
A = watershed area (km)
dQ = incremental storm-flow depth (mm)
dD = Unit duration of time used with the distribution of daily rainfall to account for the rainfall intensity variations
L = catchment lag (min)

SOIL CLASSIFICATION AT THE STUDY SITE

In Zimbabwe soil classes consists of four orders namely Amorphic, Calcimophic, Kaolinitic and Natric (Thompson, 1965; Soil Map of Zimbabwe-Rhodesia, 1979). Soil at the University of Zimbabwe campus is classified under the kaolinitic order and fersiallitic group (Nyamapfene, 1991). The following soil properties were established (Nyamapfene, 1991):

Table 2 Soil properties established at the University of Zimbabwe campus

Clay %	Silt %	Sand %	Hydrological Group
40	21	39	B
45	20	35	B/C
60	16	24	C

From Table 2 and using the SCS-SA User Manual soils hydrological group can be derived (Schulze *et al*, 1996;).

CREATION OF THE DEM: DATA INVENTORY AND DATA SCREENING

The following steps were adopted in creating the DEM for the University campus:

- Using software Adam 3DD System, aerial photographs of scale 1: 5000 were digitised to obtain spot heights. The control co-ordinates on the aerial photographs were few, so to aid on accuracy co-ordinates obtained through a ground survey were used to densify the photo control.
- To check for registration some buildings and roads were digitised from the aerial photographs, these digitised buildings and roads were then overlaid on the U.Z map obtained from digitising a 1:7000 map.
- A regular grid DEM was produced from the spot heights (Surfer, 1990). With the land-use map overlayed, drainage patterns were extracted (Figure 3). Importing the DEM from surfer into ArcView results in loss of spatial attributes i.e. no co-ordinates could be obtained from the DEM hence no analysis could be made.
- Alternatively a surface (DEM) was created in ArcView from an ASCII file (derived from the spot heights). In Figure 4 the embedded table shows the Z value of a point on the surface, and the X and Y values are displayed on the top right hand corner of the main window.
- From the surface, contours of one metre interval, a slope and an aspect map were created. Further processing was done using ArcView Spatial Analyst.

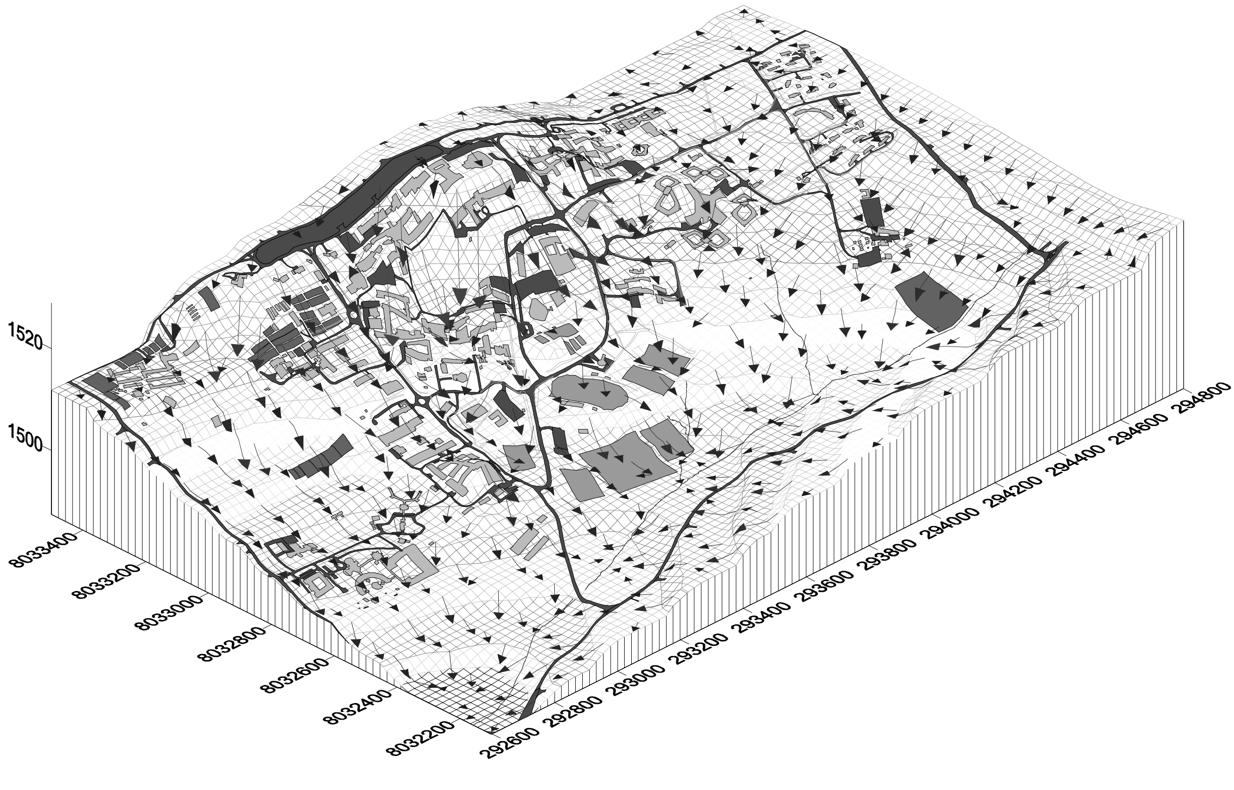


Figure 3 University of Zimbabwe DEM showing flow directions and land-use.

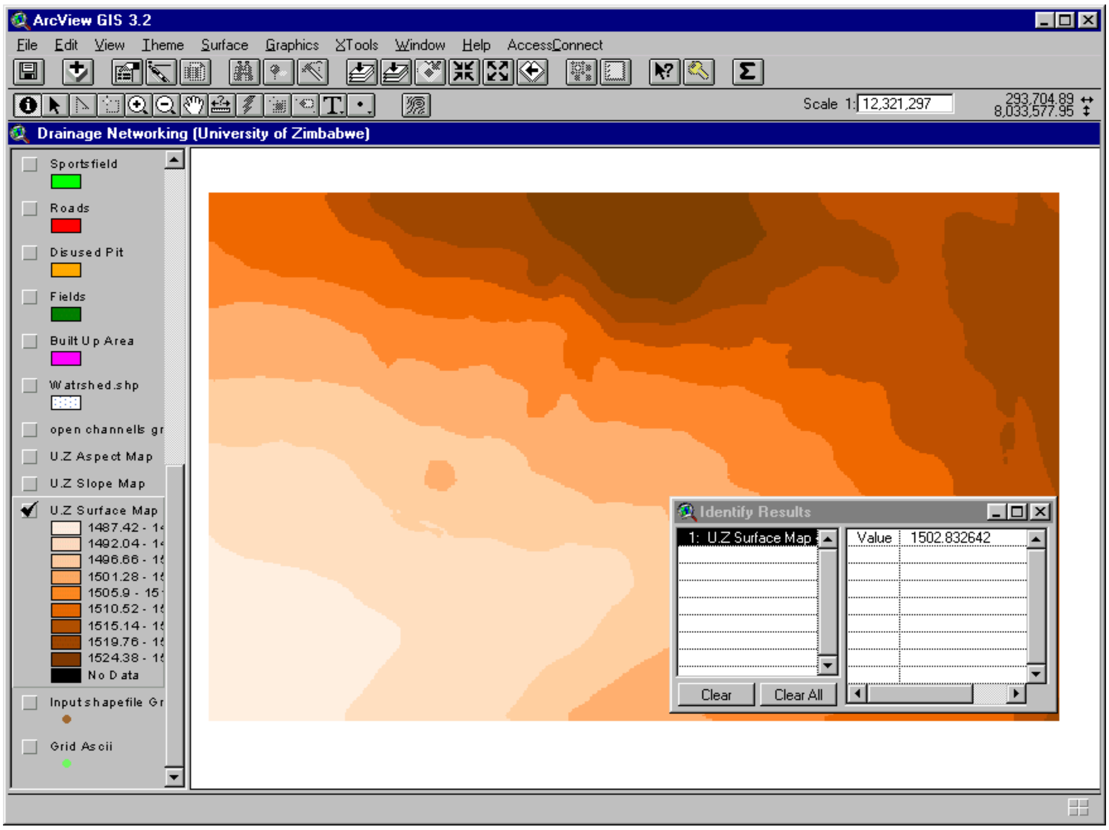


Figure 4 University of Zimbabwe DEM in ArcView

DATA PROCESSING IN ARCVIEW

The surface produced was converted to a raster DEM. The next step involved filling pits or ponds, which are cells where water would accumulate when drainage patterns are being extracted. Pits are a sign of error in the DEM due to interpolation. Their frequency is affected by grid cell size. The command fill under "Hydro" in spatial analyst does this step. After filling the sinks the next step was to determine flow accumulation grid from the DEM and finally to delineate the watershed.

Watershed delineation was executed automatically by calling the watershed command under the "Hydro" extension in ArcView. The watershed is delineated from the flow accumulation grid hence this grid theme has to be the active when watershed is being delineated. As shown in Figure 5, a total of 30 sub-basins were delineated and these constituted the watershed. Attributes of these sub-basins include mean slope (from slope map theme), mean elevation (from DEM theme), area and perimeter of the each sub-basin.

ESTIMATING RUNOFF

A soil map was digitised with each soil group being treated as a polygon. Using the ArcView x-tools extension a land use map was produced by merging roads, buildings and sports fields. The soil and land-use maps were then intersected to come up with a single soil-land-use map. The soil-land-use map was then combined with the watershed map to produce a soil land-use watershed map. The attributes of this map were basin id, area and perimeter of basin, area of land-use within each basin, mean slope, and land-use and soil category. These attributes were used to determine the CN_i value for each area. CN_a was then computed using Equations 3 and 4 to cater for antecedent soil moisture conditions. The equation to use is dependent on the SCS classified pentad condition shown in Table 3.

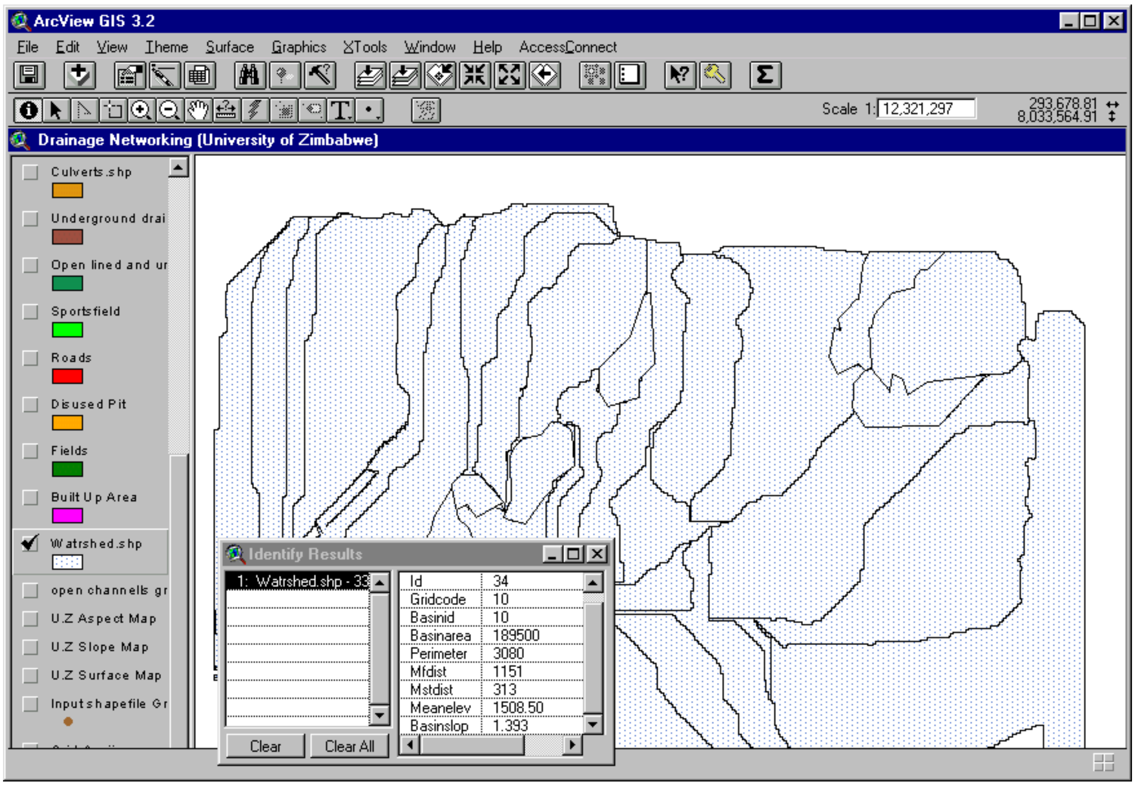


Figure 5 Delineated watershed

Table 3 SCS Pentad antecedent moisture condition classifications

Five Day Antecedent rainfall (mm)	Antecedent Moisture Condition (AMC)
< 35	Dry
35 to 52.5	Average
> 52.5	Wet

Using CN_a values, runoff was computed (N.B. no adjustment is done if the condition is average) using Equation 1; multiplying by the area of the theme in question, volume of the runoff was obtained. Calculations were done for various rainfall depths in each case the CN_i value being adjusted for dry or wet antecedent soil moisture conditions.

Further calculations were done to determine the T_c for each basin i.e. CN_c was determined for each basin using Equation 2. Using the calculated CN_c values and flow length and average basin slope obtained from watershed delineation, the individual basin lag times were obtained using Equation 5. Equation 6 was then used to determine the T_c.

From the analysis of the daily rainfall data collected for the two stations at the University of Zimbabwe campus the variation of the maximum one-day rainfall for each month for the three-year period was established. The range of the one-day maximum (design) rainfall for the recurrence interval of three years was 25 to 75 mm/day. Peak discharge was computed for the 25mm, 50mm and 75mm/day design storm-flow depths for each sub-basin by substituting for P in Equation 1. In the absence of synthetic time distribution curves it is assumed that the day's design rain falls in a short duration of one hour. Then using Equation 7 peak discharge was calculated for each sub-basin using a 25mm deep design storm and wet AMC as an example.

RESULTS AND DISCUSSIONS

The average runoff and peak discharge from each basin was computed using the SCS method and wet AMC condition. A comparison of the runoff volumes generated confirmed that runoff volume is a function of the catchment characteristics and storm depth. By superimposing the existing physical drains on the DEM containing automatically generated flow lines, the orientation of the drains was assessed for effectiveness. Although there were difficulties in associating each drain leg to a particular sub-basin.

For the engineering design of drains, the peak flows can be used with either the Manning's Equation or relevant design charts to obtain the dimensions for each drain leg. This is an iterative process to ensure that the drain dimensions, and therefore its capacity can at least withstand the peak runoff determined in Equation 7. The reconstructed concrete lined drains at the University of Zimbabwe are on average 0.5m deep, bottom width of 0.4 m and the sides inclined at about 60° to the horizontal. It is also important to note that in sizing the drains, economic factors and design standards or code of practice play an important role. The model described in this paper is useful up to as far as calculating peak discharges but not the actual engineering design of the drains. A simple spreadsheet based on Manning's equation can be used to achieve this.

CONCLUSIONS AND RECOMMENDATIONS

Data on terrain, land-use and hydrology of the University of Zimbabwe campus was converted to information for storm drainage network planning. Photogrammetry was used to gather data for DEM creation because of the fast acquisition of data. Runoff hydrographs can be created for "before" and "after" construction. The change in runoff as a result of a new development can be estimated for the sub-basin or watershed. The combination allowed siting, location, orientation and modelling of impact on the change in the flow direction of runoff. The SCS-SA method employed to estimate runoff works well in a GIS environment because of its relatively simple equations, which do not require extensive programming, which is not, supported by GIS packages. The estimation of runoff volume can be improved by manually determining the constants for the SCS-SA equations for the area under study. This can be best done by manually measuring runoff volumes at sub-basin outlet points and then comparing the volume measured against that obtained by using a DEM for the prototype area.

ACKNOWLEDGEMENTS

The authors would like to acknowledge with immense appreciation the SIDA-SAREC funding awarded through the University of Zimbabwe Research Board to enable this research (Project No. 3YRR10/0007: Options for local recycling of waste (Grey) water at the University of Zimbabwe Campus).

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The challenge of integrated water resources management in the Chivero Basin, Zimbabwe

R. HRANOVA[1], B. GUMBO, E. KASEKE, J. KLEIN, I. NHAPI and P. van der ZAAG

Dept. of Civil Engineering, University of Zimbabwe, PO Box MP167, Mt. Pleasant, Harare, Zimbabwe.

[1] hranova@eng.uz.ac.zw

ABSTRACT

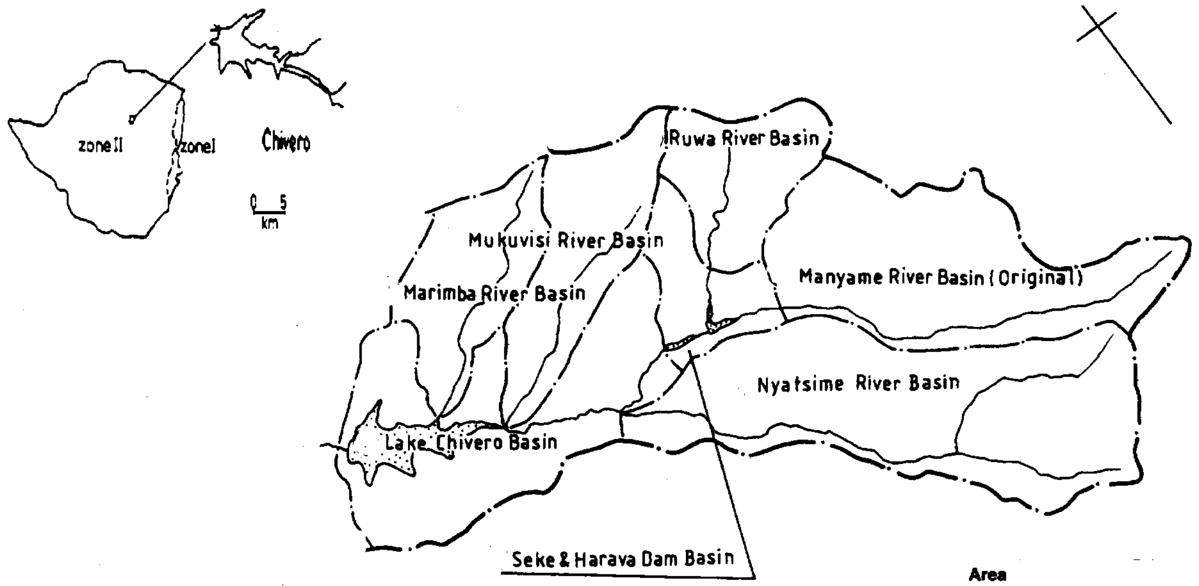
This paper summarises the results of a study on different aspects of integrated water resources management in the Lake Chivero basin, which is the main source of water supply of the City of Harare, Zimbabwe. The key-areas of investigations were: water quality and pollution fluxes; environmental aspects; water quantity modelling; urban water management and finally outreach and stakeholder participation. In terms of water quality, fluxes of N and P have been estimated, and an integrated database has been developed in order to analyse and evaluate existing monitoring techniques and identify critical sources of pollutants. In environmental terms a study was undertaken towards the development of a biological water quality monitoring and evaluation system, based on habitat characterisation. As to water quantity, it was found that the existing infrastructure is inadequate to satisfy water demand for the greater Harare area. It is not yet clear how some provisions of the new Water Act, such as the recognition of the environment as a legitimate water user, will be implemented. With regard to urban water management, the research focused on the development of a rainfall runoff model for the composite catchment area of the Marimba river basin, a sub basin of the lake Chivero catchment. The objective was to quantify urban storm runoff, its pollution potential and to demonstrate the potential impact of alternative land uses on storm water management in a suburban micro catchment. Regarding stakeholders' participation in the management of the basin, the study focused on the youth. It appeared that the youth' knowledge on formal issues related to water is limited, but that in practice they are often actively involved in environmental management. The paper discusses the above findings, identifies the principal causes of the problems and suggests integrated solutions. The extensive amount of data accumulated and analysed during this study could form a sound basis for the development of a Management Information System of the basin, based on a GIS. Such a system could be useful for the catchment councils involved.

Keywords: *biomonitoring; stakeholder participation; urban drainage; water allocation; water quality monitoring; water resources management*

1. INTRODUCTION

Lake Chivero is a manmade reservoir, located near Harare, the capital city of Zimbabwe. Its watershed consists of different land use patterns - low inhabited areas in the upper reaches, commercial and communal agricultural land uses, and densely populated urban developments, including Harare and the satellite towns of Ruwa and Chitungwiza. The total population in the basin is believed to exceed 2 million. Due to its downstream location the Lake is the natural sink of the surface run-off and effluents from the above mentioned areas (Figure 1), and is heavily eutrophied. Its major beneficial use is to supply a major part of the potable water demand for the City of Harare, but it is also a well-established recreational centre and the natural environment for a wide variety of wildlife. This complex pattern requires an integrated approach to the water resources management practice. An attempt to investigate and discuss different aspects of existing practice and possible ways of improvement and integration is summarised in this paper. The study has been performed in close collaboration with the Department of Water Development (DWD), the Department of National Parks and Wildlife Management, the local authorities of the City of Harare and other stakeholders involved in water resources management.

The paper first summarises the findings of the five key-areas of investigation, namely water quality and pollution fluxes; environmental aspects; water quantity modelling; urban water management and finally outreach and stakeholder participation. These findings are then discussed in their interrelationships, and ways towards solving the current unsustainable situation are suggested.



Basin Name	Area (km²)
Lake Chivero Basin	420
Marimba River Basin	230
Mukuvisi River Basin	230
Nyatsime River Basin	590
Sub-Total	**1 470**

Basin Name	Area (km²)
Seke & Harava Dam Basin	120
Ruwa River Basin	180
Manyame River Basin (Original)	480
Sub-Total	**780**
Total	2250

Figure 1: Map of the study area

2. KEY AREAS OF RESEARCH

2.1 Water quality and pollution fluxes

Previous research shows that Lake Chivero is in advanced state of eutrophication (Moyo, 1997). This is corroborated by Nhapi *et al.* (2001b), who also found that the quality of the river water flowing into the lake exceeded the permissible effluent discharge regulations by a factor 10 or more for Total Nitrogen and Total Phosphorous. Pollution fluxes into the lake originate from commercial agriculture, industries and households. Current treatment capacity of sewage stemming from the main urban areas is insufficient. The recycling of polluted waters in the Chivero Basin further exacerbates the problem.

Given the critical state of the basin in terms of pollution, there is a great need for proper data collection and organisation, which could help the identification of critical sources of nutrients. The methodology applied in this key area of investigation consists in the creation of an integrated database, including: a) historic data based on literature sources; b) data extracted from the records of two independent monitoring programs at DWD and at the City of Harare for the period 1995-2000; c) experimental field work on river water quality at specific site locations during 1999-2000.
The database is organised in four major groups: surface water quality (including major rivers and lakes in the basin), effluent discharges, urban surface runoff (surface drainage channels and small streams), and ground water. A coding system has been developed to identify all sampling point

locations and to allow the integration of all data collected for each specific site. Excel spreadsheets are used to organise and analyse the data in terms of statistics, temporal and spatial variations. At this stage the database contains data for surface water quality, effluents and the abstraction point in Lake Chivero, but in future it could be expanded to include additional data sets.

The coding system comprises of letters and numbers arranged in four major positions, separated by strokes: N1/N2/N3/N4. N1 is the code for group identification (surface water- rivers, streams and lakes, effluents, storm runoff – drainage channels and streams, and ground water). N2 is the code of the subgroup, identifying name of rivers, lakes, effluent discharges, etc. N3 code identify the source of information – continuous monitoring program of DWD, CH or research project, and the N4 code stands for the number of the sampling point location within the subgroup. As an example the identification code R/Mn/Ch,Cr/2 should be read as sample point 2 on Manyame River, data obtained from the monitoring programs of CH and DWD. The information for this specific point is contained in a separate file, where the data from the two sources are presented separately.

The structure of the database, as shown on Figure 2, is based on the coding system adopted. Folders A, B, and C are common for all files. Folder A contains information regarding the location of all points included, illustrated in a schematic map and supported by explanatory text. Folder B contains description of the laboratory analytical methods used by the different sources of information, and folder C contains information regarding numbered research projects and other sources, which do not perform continuos monitoring programs. The files for each specific sampling point contain information regarding date of sampling, parameters tested, number of laboratory analysis and general remarks. Under this specific project, the data already collected and organised focuses on nutrients (Total N, Total P, TKN, ammonia and nitrates) and some supporting parameters as pH and conductivity. It should be noted that this first attempt to create an Integrated Water Quality Database is open for further extension, improvements and the authors are aiming to incorporate it in a future GIS system.

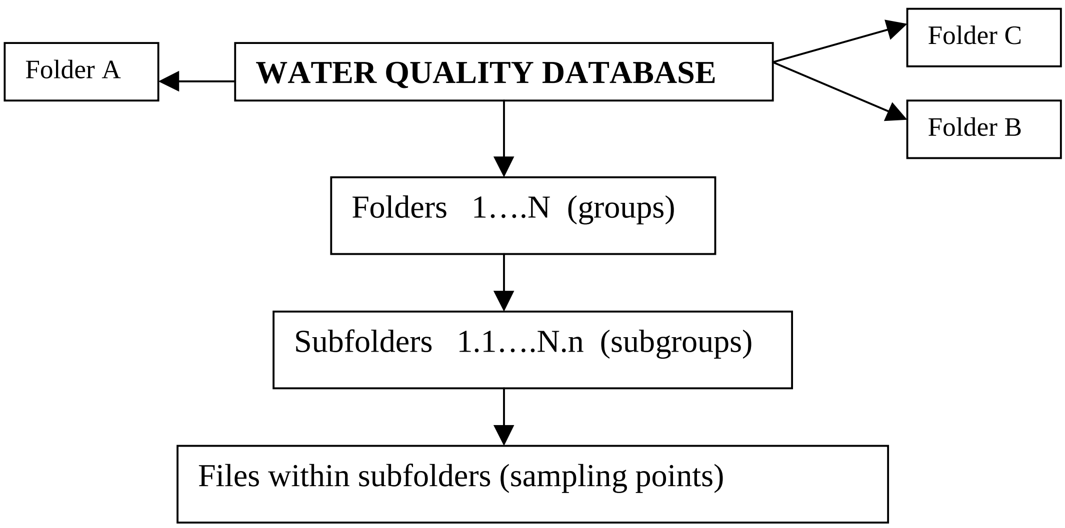


Figure 2: Structure of the database

The following aspects of integration are achieved at this stage of development:
Integration of different data sources – it increases the volume of data available and helps in the analysis and streamlining of the continuous monitoring programs. Avoiding duplication of efforts, identifying critical locations, and comparing data from different laboratories and analytical methods will help to improve the reliability and cost effectiveness of the monitoring programs (Bollinger, 1999; Ongley, 1998)

Integration of different types of water monitored – the integration of data for effluent discharges and rural and urban runoff with the surface and ground water quality would allow to assess and analyse the impacts of polluted fluxes to the water environment and the identification of critical sources of pollution.
Integration of different time series - the integration of data from monitoring programs and those from research projects allows analysis of data sets with different sampling frequency. Usually, research projects and specific investigation provide data with shorter duration but with higher sampling frequency, which allows more detailed analysis of spatial and temporal variations at specific locations.
Spatial integration - the integration of all sources helps the analysis and comparison of spatial variations of water quality for the whole basin, which would be a sound basis for the application of the principle of catchment management in practice.

Incorporation of this database in a GIS, together with other databases containing data on water quantity, rainfall and land use practice, would allow:

- estimation of pollution fluxes and pollution loads from point and diffuse sources,
- mass balances regarding water quantities and different water quality parameters,
- elaboration of water quality indices as a simple tool for water quality monitoring (Lauver, 2000; Pesce, 2000)

The analysis of the data accumulated will be subject to a separate publication, however a preliminary overview points out to the following:
Regarding the continuous monitoring programs of DWD and CH - there are many gaps in the records regarding the frequency of sampling, e.g. at location R/Mr/Ch,Cr,R_5/ 8 (after the effluent discharge of Crowborough Wastewater Treatment Works), the frequency of sampling varies from 1 sample per year to 5 or 6 samples per year. This does not allow a proper statistical analysis of the data collected. Also, considerable and consistent differences were noticed in the results obtained from the two monitoring programs related for the same location and at similar time of sampling, especially regarding nitrates. This is an indication of disparities in the analytical methods applied at the two laboratories.
Regarding time and spatial variations of river water quality – time variations at R/Mr/Ch,Cr,R_5/ 8 show that the highest concentrations for nitrate of 13 mg/l. was recorded in 1996, recent years showing decrease in the concentrations in the range 0.7 – 1.3 mg/l. A comparison of Marimba River water quality at location 1 (R/Mr/Ch,Cr,R_5/ 1 - upstream, within medium density urban residential area) and location 8 (R/Mr/Ch,Cr,R_5/ 8 – downstream, before the discharge to Lake Chivero), shows considerable increase in the level of Phosphates from 0.2 – 0.3 mg/l at point 1 to 6.0 – 8.0 mg/l at point 8, which is clear indication of pollution, contributed from industrial and municipal effluent discharges. In general a trend of deterioration of effluent water quality in terms of nutrients was found during the period of study, which is due to increased hydraulic and pollution loads to the existing treatment facilities, as well as to operation and maintenance problems as reported by Nhapi et all, 2000a,b.

2.2 Environmental aspects

Through the establishment of reference sites, and the associated characterisation of biological, chemical and physical parameters, a first step was made towards the development of a simple model, linking the a-biotic parameters of a sampling site with the expected composition of the aquatic community (Mashava, 2001). The deviation in the actual ecological characteristics of a site from the condition expected on the biotope characteristics serves as a yardstick for the degree of pollution occurring at each site and, through the application of a GIS-based approach, of the spatial distribution of pollution impacts. This facilitates the definition of trends and therefore represents a useful communication and management tool. The output of the system will be a colour-coded map of 4-5 water quality classes.

The research covered the whole of the Manyame catchment, including the Chivero basin, in order to include a sufficient degree of natural variation. The main sources of pollution are associated with the City of Harare and several major industries in the Upper Manyame Catchment. Additional sources are from mining and agricultural activities. As a result, the sites within the area with relatively undisturbed conditions are mainly limited to first order streams. On the basis of a desk study and subsequent field visits, a total of fifty potentially suitable sites were identified and evaluated. Only eight turned out to be acceptable. Main reasons for the elimination of the other sites were local pollution sources or accessibility problems. The remaining sites are situated in an altitude range of 1150 – 1550 m. The water quality characteristics for these first and second order streams are rather uniform, with temperatures ranging from 20-25^0 C, pH values between 6.8 and 7.1, generally low turbidity and with conductivity values below 56 μS/cm in the upstream parts of the catchment area, and values between 100 μS/cm and 270 μS/cm in the lower catchment. The variation in physical characteristics was far more pronounced, with flow velocities ranging from 0.9-3.2 m/sec, channel depths from 23-55 cm and widths from 1.6- 5 m. Discharges at the time of investigation (during the rainy season) varied between 0.6 and 2.8 m^3/sec.

The biological characterisation was done with the South African Scoring System version 4 (SASS4) approach (Thirion, 1995), using the presence and pollution tolerance or sensitivity of selected macro-invertebrate orders and families to classify the different sites. The three groups that were most frequently found were mayfly larvae (*Baetidae*), caddisfly larvae (*Philoptamidae* and *Hydropsychidaea*), and blackfly larvae (*Simulidae*). Each of these groups prefers a specific combination of food supply, dissolved oxygen level, flow velocity and type of substrate. The first two are related to organic pollution levels, while the latter determine the basic suitability of the site.

The substrate and biotope characteristics, including the possible variation in time, especially with a pronounced dry and wet season and the associated variation in water levels and flow velocities, define the probability of the occurrence of individual species, families and assemblages of the different groups. A significant deviation from the expected biodiversity at a site will be an indication of pollution, with the degree of change being a measure of intensity and/or duration of the impacts. The results of this study are presented in Table 1.

Table 1: Selected habitat characteristics

Site:	1	2	3	4	5	6	7	8
Bottom Characteristics (%)								
Silt/Clay	100	60		20		5		
Sand		30	75	30	5	5	5	5
Gravel & Boulders		10	25	50	95	90	95	95
Habitat Characteristics (Score)								
Variation in bottom substrate	5	10	10	20	15	20	20	20
Distribution of sediments	20	20	20	15	20	10	15	15
Biotope diversity	5	15	15	15	15	15	20	20
Velocity/depth	10	10	10	10	10	5	5	10
Scouring & deposition	5	10	5	10	10	15	10	10
Variation in channel morphology	10	15	15	10	10	15	10	15
Bank steepness	5	10	10	10	5	10	10	10
Dominant riparian vegetation	5	5	10	10	5	5	10	10
Total:	65	95	95	100	90	95	100	110
Diversity (ASTP; average score per taxon)	5	5	11	8	6	5	5	7
SASS4 score	**73**	**31**	**87**	**61**	**56**	**61**	**29**	**57**

As sophisticated approaches, using the RIVPACS (River Invertebrate Prediction and Classification System) or PHABSIM methods, are not (yet) applicable in the Southern African region due to the need of a large amount of detailed data, the approach that has been applied is a simple investigation of correlation between a number of selected habitat characteristics, classified in a limited number of categories.

On the basis of these preliminary data, no clear results emerge. This is probably due to the similarity of the sites, at least on the basis of the selected parameters and the applied scoring system. A broadening of the database as far as the number and location of sites is concerned is required, probably combined with a refinement of the habitat classification system towards a better discrimination of spatial and perhaps temporal variation.

2.3 Water quantity modelling

A spreadsheet-based model was developed that uses data on water generation and water use, and generates water flows into Lake Chivero. The purpose of the model was to assess the implications of the new Water Act of 1998, and specifically the abolishment of the prior date system, on existing and future water use. The model simulated historically observed storage levels over the period 1970-1997 well (r^2=0.96). Different scenarios were run, which are reported in Natsa *et al.* (2000). Some relevant findings are summarised here:

1. With Biri dam (phase 1) in place (downstream of the Chivero basin), the existing infrastructure is insufficient to satisfy current water demand in the Chivero basin. This points to the urgent need for Harare to manage its water demand and decrease system losses (currently believed to be around 40%); and to construct the proposed Kunzwi dam in the Mazowe basin. Nhapi *et al.* (2001b) arrived at a similar conclusion from a different perspective.
2. The Water Act of 1998 gives priority to water use for primary requirements. It is still unclear how the principle of primary requirements will be interpreted for urban water use. The consequences of such interpretation for the various water users should be estimated.
3. The new Zimbabwe water legislation considers the environment to be a legitimate water user. It is as yet unclear how the environmental requirements will be translated into water permits, and hence what the implications will be, both for the environment as well as for current water users. The impact on the resulting flows in certain critical points in the river, as well as on existing permitholders, should be analysed. These findings can then be fed into the research activities on water quality and environmental aspects.
4. Since changing the water allocation system affects the yields of dams, it is necessary to revisit existing official and practised operation rules of dams in face of water shortage.

2.4 Urban water management

Urban storm water estimation and management presents an intriguing problem in the puzzle of the urban water cycle. Marimba river catchment is a sub-catchment of the Chivero basin covering about 190 km^2. The catchment can be classified as partially urbanised and the main stream meanders from urban to rural areas for about 50 km, from an altitude of 1470 m above sea level before discharging into the lake at about 1370 m. Table 2 shows the breakdown of land use within the catchment. More than 50 % of the urban or municipal area was developed after 1980. Rainfall data from four stations obtained from the Meteorological Services Department was analysed, together with land use and soil data in order to estimate runoff. The SCS-SA (Schulze *et al*, 1992; USDoA, 1986), rainfall-runoff model was used to estimate both runoff volumes and peak runoff. Runoff recorded at Station C24 at the mouth of Lake Chivero on the Marimba River was obtained from the DWD and used to calibrate and validate the model.

Although the Marimba and its tributaries are supposed to be naturally ephemeral, the rivers flow throughout the year because of the urban return flows that include effluent discharges. The average monthly flow from 1953 to 1999 is depicted graphically in Figure 3.

Table 2: Land use of the Marimba catchment derived from topographic series maps.

Land use	Area (km^2)	% of total area
Urban/ municipal	126	67
Rural	63	33
Total	**189**	**100**
Urban		
Industrial parks	5	3
Central Business District	3	2
Low density residential	49	26
High density residential	39	21
Open spaces (parks, cemeteries, gardens, golf courses)	30	15
Rural		
Cultivated farm land	29	15
Bush /forests and woodlands	34	18

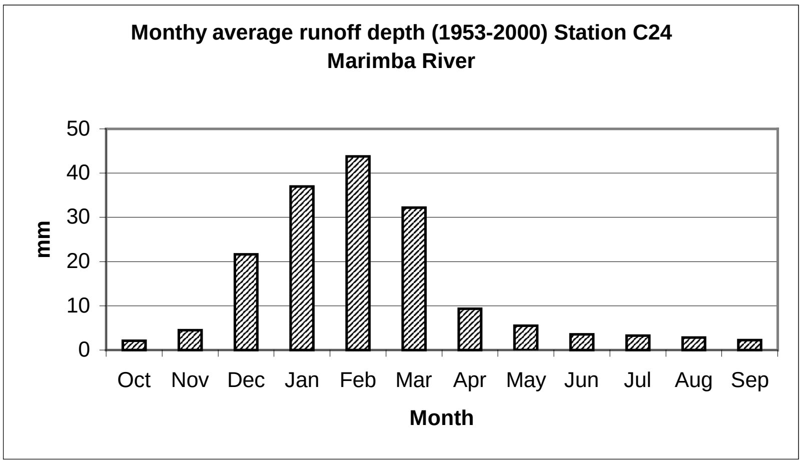


Figure 3: Average monthly runoff depth, Station C24 on Marimba River (1953 to 2000)

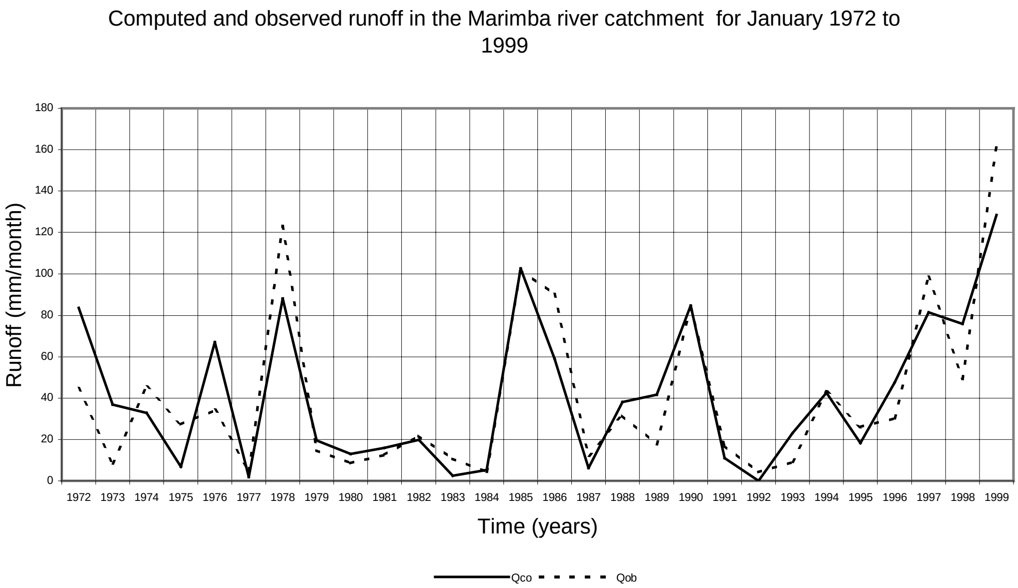


Figure 4: Comparison of computed and observed runoff depth for Marimba River catchment

A lumped multiple linear regression model was developed for a composite Marimba river catchment area (Chidavaenzi, 2000). The model is specific for the individual catchment area and requires only readily available daily rainfall data as input to estimate runoff depth. Observed flow (Q_{ob}) and computed (Q_{co}) at point C24 are illustrated graphically for the months of January (Fig.4). A correlation coefficient of 75% was attained on average showing a good fit between the observed and computed storm runoff depth.

The rainfall runoff model developed can be used in combination with water quality data to calculate and predict pollution loads due to storm runoff from the Marimba catchment. Figure 4 suggests a gradual increase of storm depth with time, especially after 1980 when significant urbanisation (impermeabilisation) occurred.

2.5 Outreach and stakeholder participation

One of the four main principles at the core of Integrated Water Resources Management (IWRM) as enunciated in the Dublin Principles states that water development and management should be based on a participatory approach that involves users, planners and policy makers at all levels (SADC, 2001; Solanes *et al.*, 1999; GWP, 1999). In short, this is the principle of stakeholder participation. One of the main objectives of this principle is to ensure acceptance and ownership of water development projects by intended beneficiaries as well as the long term sustainability of those respective projects. Also emphasised within IWRM is timely provision of information to decision makers for effective water management in a participatory manner (Haddad, 1996).

The Lake Chivero research project recognised the need to jointly share responsibilities with stakeholders in the Upper Manyame Catchment in the quest to find feasible solutions to the respective water quantity and quality problems through research. The stakeholders involved in research work in the five themes are primarily the Ministry of Rural Resources and Water Development, the Upper Manyame Catchment Council, the City of Harare, Chitungwiza Municipality, Zimbabwe National Water Authority (ZINWA), Environment 2000 and the Scientific and Industrial Research and Development Centre SIRDC. Also recognised was the need to involve marginalised stakeholder groups such as the youth who are quite active in issues to do with environmental management.

A workshop was held with the objectives of establishing the youth's knowledge level of IWRM, the water and pollution problems besetting Lake Chivero, their level of participation in programs aimed at ameliorating these problems, identification of gaps that the research project could contribute with knowledge. Workshop participants were drawn from Environmental Youth Clubs from 15 primary and secondary schools in Harare and Chitungwiza, Boy Scouts, teachers, City of Harare junior councillors, the Zimbabwe Youth Forum, Environment 2000's Lobbying and Advocacy Unit and University of Zimbabwe academics (Kaseke, 2001). The main findings of the workshop were as follows (Kaseke, 2001):

1. The youth have no knowledge of the IWRM concept and what it entails; nor have they insight into the water legislation, and water development and management institutions such as ZINWA.
2. They are all actively involved in aspects of environmental management, such as soil erosion prevention and gully reclamation, water pollution awareness projects and anti-litter campaigns.
3. Through the clubs, the youth have a structure for networking and information exchange (e.g. drama groups) and are quite aware of the water pollution problems being experienced in the Upper Manyame Catchment especially the Mukuvisi River and Lake Chivero.
4. They neither have the knowledge or the techniques and tools for monitoring water quality.

With respect to the workshop outcomes, it is therefore recommended:

1. To involve the youth in IWRM and identify the roles they are to play as stakeholder participants, especially in the monitoring and evaluation of water and environmental quality.
2. To develop a strategy for educating the youth on IWRM with some of the components being the development of simplified education materials on IWRM, holding of youth workshops, implementation of visual art displays, drama and other awareness activities on IWRM. Rand Water's schools water action project in South Africa is a reference case that could be emulated with respect to this recommendation (DEC, 2000).
3. To incorporate the existing youth network structures such as Environmental Clubs and Boy Scouts as IWRM stakeholder participants into the catchment councils.
4. To use the findings of the current research, and specifically those related to water quality and environmental aspects, in order to develop (a) simple but cost effective and efficient water quality analysis techniques and (b) bio-monitoring techniques. It is anticipated that youth groups will use these tools for water quality evaluation and monitoring.

3. DISCUSSION AND CONCLUSION

The preliminary research findings concerning five key areas of the management of water resources in the Lake Chivero Basin paint an interesting picture of an, as yet, unsolved puzzle of current problems as well as possible solutions. Since the aim of this multidisciplinary research project is to add value to the various disciplinary aspects studied, and to suggest ways of solving the present problems in the basin, this section attempts to put together the pieces of the puzzle.

The principal finding is that the current situation in the basin is unsustainable in terms of water use and water pollution. Urgent measures need to be taken in order to avert a serious crisis that could affect the livelihoods of 2 million people, and the economy of Zimbabwe. The immediate causes of the problems could be identified as:

1. The main water source of the urban centres in the basin is also the sink of their waste. As much as 30% of the water flowing into Lake Chivero is reused, part of which (some 25%) flow back into the Lake with a higher pollution load, thus continuously increasing the pollution concentrations.
2. The existing urban water supply systems experience high water losses, leading to unnecessary high demands for raw water, as well as to bottlenecks in the distribution network that could be avoided.
3. The capacity of some sewage treatment plants is insufficient, others are used sub-optimally due to operation and maintenance problems.
4. The enforcement of effluent discharge regulations is insufficient and some of the producers of pollutants do not receive the signals required towards reducing sewage loads.
5. Diffuse sources of pollutants, such as those emanating from commercial agriculture, are as yet unmonitored, but could be a significant source of pollution, while consuming large quantities of water.

To address the above causes solutions have to be sought in terms of both "hardware" and "software" simultaneously.

Hardware solutions

Two capacity problems need urgent attention:

(1) More water should be made available from outside the basin, while at the same time the efficiency of the water supply distribution system should be increased. Halving current water losses would increase the capacity of the distribution network by some 20% and decrease raw water demand by a similar percentage.

(2) The sewage treatment capacity should be increased, both by increasing the efficiency of existing plants, and adding new plants, while at the same time effluent loads should be reduced

through investing in cleaner production technologies and practices in industry as well as in commercial agriculture

Software solutions

(1) Any "software" solution will have to be based on proper information and an increased understanding of the processes. The crux therefore is efficient monitoring of all water and nutrient fluxes in the basin. If this information is available, existing legislation on water use permits and effluent discharge permits can be enforced, which is likely to result in higher water use efficiencies and lower pollution loads.

(2) “Software” solutions will have to be based on the new stipulations in the Water Act of 1998, its new stipulations. Much depends how these will be translated operationally. Specific attention should be given to the status of primary water requirements, water requirements of the environment, and the role of ordinary citizens in the new catchment councils. In addition, operation rules of dams have to be revised in face of the abolishment of the prior date system of water allocation.

While the problems in the Chivero Basin are huge, the above shows that there is scope for solving these. The opportunities created by the new water legislation are significant. If adequately implemented, the legislation will lead to more equitable access to water, to cost recovery for services, to polluters paying so that there will be an incentive towards cleaner production processes, and to stakeholders having an important voice in managing the water resource, as well as in monitoring the state of the resource. Much will depend on how the Catchment Councils and Sub-Catchment Councils will take up the huge challenge of translating the noble intentions and objectives in the legislation into new management and operational practices.

Our investigation has the potential to assist these authorities. The main contribution we can make is to assist them in developing a Management Information System of the basin, based on GIS. It should incorporate data about water resources in terms of quantity and quality, rainfall and land use. It could be used as a yardstick to evaluate and formulate present managerial strategies, as well as a planning tool for future development solutions. Moreover, it would allow the integration of the data accumulated and the calculation of water quantity balance, planning of future water uses and issuing of water permits and the modelling of different scenarios of quantitative and qualitative aspects within the catchment, in order to elaborate optimal managerial solutions for social development and environmental protection.

In addition, we would like to get involved in awareness campaigns and training programmes in order to provide the necessary knowledge and tools to catchment councillors and the wider public in order for them to be able to make the difficult decisions that are urgently required.

ACKNOWLEDGEMENTS

The authors acknowledge the research grant received from WARFSA. We also acknowledge the support received from DWD and the City of Harare authorities, as well as the research assistants and the technical staff of the Department of Civil Engineering, University of Zimbabwe.

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The credibility of an ant flood forecasting, hydrological models, credibility and communication in Mozambique

Marijke JAARSMA & Herbert BOS, Carin VIJFHUIZEN[1] & Adelaide GANHANE

Faculty of Agronomy and Forestry Engineering, Eduardo Mondlane University, Maputo, Mozambique

[1] vijfh@zebra.uem.mz

ABSTRACT

In January this year, a considerable part of the population living in the flood plains of the Zambeze River, near Mutarare, left their machambas (fields where they cultivate) and moved to higher areas. They told a representative of the National Water Directorate, who was then visiting the area, that they were leaving because of the ants who had also moved to higher areas, indicating that there would be a flood this year. One month later, the Zambeze River was flooded.
As we were all involved, in one way or another, in the floods of 2000 and 2001, we were eager to investigate why flood forecasting in Mozambique has not, as yet, been able to achieve the credibility accorded to the ants.

Floods in Mozambique are natural phenomena that occur frequently due to the geographical position and geomorphological circumstances of the country. Floods in 2000 (South) and 2001 (Zambeze and Pungué) caused the loss of over 700 lives, as well as extensive infra-structural and economic damage. Hence, flood forecasting in Mozambique is a very essential life-saving issue.
Flood forecasting is based on real-time information about water levels, discharges and rainfall in the river basin. Besides this, other information like discharge curves, travel times, rainfall run-off factors and topographic elevation of the riverbed is essential to achieve the final goal: prevision of inundated areas downstream. Given the present situation of very limited available data in Mozambique, the authors are convinced that improvement is necessary in the communication of the (very general) message to the population. Currently, the collected data is disseminated through bulletins in very technical language and is interpreted by authorities who then pass on the information to different levels.

In a case study, the authors interviewed the population of Conhane, a small village in the Limpopo River Basin, about the accuracy of the flood forecasting. Most people said the message was clear and given in good time. However, they only left their houses when they could see with their own eyes that upstream areas were already flooded.
The paramount issue that emerges is how to improve flood forecasting and thus formulate credible messages. This implies improvement on all fronts: not only technical but also, above all, in the communication of the message to the people. If the right wording is used then perhaps, in the future, the hydrologists will be just as credible as the ants.

-Marijke Jaarsma is a hydrologist and worked in the Regional Water Authority of the southern rivers of Mozambique and is currently a consultant to UNICEF in Maputo, Mozambique. She was involved in the flood fore casting of 2000 (mjaarsma@seed.co.mz).

-Herbert Bos is a hydrologist and works as a consultant (SEED) in the National Water Directorate of Mozambique. He was responsible for the flood fore casting at the National Water Directorate during the floods of 2001 (hbos@seed.co.mz).

[1]-Carin Vijfhuizen is a Rural Development Sociologist and Gender Specialist and is currently an Assistant Professor in the areas of communication and rural sociology, at the Faculty of Agronomy and Forestry Engineering, Eduardo Mondlane University, Maputo, Mozambique (vijfh@zebra.uem.mz).

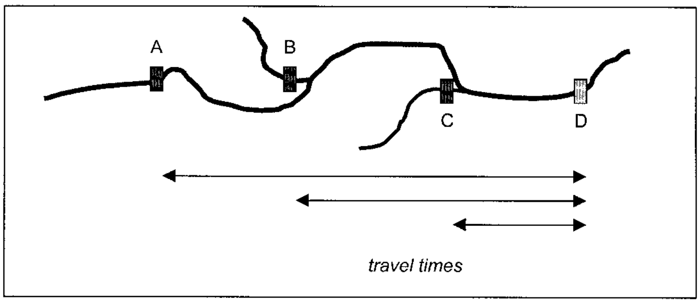
-Adelaide Ganhane is a recent graduate from the Eduardo Mondlane University. She wrote her thesis about gender and community banks in Zambezia Province Mozambique. Currently she participates in the different research programmes of the Communication and Rural Sociology Section (UEM).

GENERAL

As stated earlier, floods in Mozambique are natural phenomena that occur almost yearly, due to the geographical position and geomorphologic circumstances of the country. Extreme rainfall in the rainy season (Dec - April) over the main part of Southern Africa, caused by tropical depression zones, can easily result in floods in Mozambique as it is downstream of nine international rivers.

FLOOD FORECASTING IN GENERAL

We consider flood forecasting as being the whole process of collection, gathering, storing and analysis of available data (weather forecasts, water levels, tendencies of water levels and precipitation data and rainfall provisions) in order to prepare information, indicating expected water levels, tendencies of water levels and flows and expected inundated areas. However, flood forecasting also includes the dissemination of this information to the national, provincial and local authorities and to the population involved (Bos, 2001).



The availability of real-time data of water levels in rivers and their main tributaries, discharges of dams and precipitation in the basin are the basis for flood forecasting practices. The figure on the right represents a river and its gauging stations and shows this practice.
The flow at point D for time (t) is the summation of the discharge that passed A, B and C at (t), minus the respective travel times. For reasons of resistance and peak flattening, the final sum has to be corrected with a correction factor in order to work out the estimated discharge. When there are long distances between the stations, rain and other lateral discharges also have to be taken into account.
There is a unique relation between water level and discharges (discharge curve) for every point in the river, so the estimated discharges can be converted to water levels.
When this process is carried out at numerous points along the river, the result is water level prediction for the whole river. When these water levels are superimposed on an accurate elevation map, the levels can be transformed into expected inundation maps. This is the final information required by the national, provincial and local authorities. Based on these maps, the affected population can be informed about the expected floods.

In summary, the information needed for proper flood forecasting is:
1. Water levels of hydrometric stations, which can then be converted, according to the discharge – curve, to discharges.
2. Information of dam discharges.
3. Information of rainfall, both registered rain and rainfall forecasts (quantity, intensity and duration), which can be converted into discharges (by means of run-off coefficients).
4. Travel times and the correction factor (which includes peak flattening, resistance of the bed etc.) can be obtained from existing data and former studies.
5. Accurate elevation maps to translate water levels in inundated areas.

<u>Hydrological models</u>

The whole process described above is rather laborious and therefore hydrological models have been developed. A hydrological model is a description of the hydrologic features of a River Basin, designed in order to simulate river flow in a basin. Such a model normally consists of a GIS based Information System with detailed information about elevation, soil type, vegetation and land use of the river basin. Also the elevation of the riverbed, by means of numerous topographical sections of the river (at least every kilometre), including hydraulic constants (like Chezy) and discharge curves are to be incorporated in the model. If the model includes rainfall, rainfall run-off constants are also incorporated.

For every river basin, a unique hydrological model has to be developed based on long series of hydrological data for calibration and verification. Only if the model has been sufficiently tested (calibration) and has been proven to describe the river flows correctly (verification), can it be used for flood forecasting.

FLOOD FORECASTING IN MOZAMBIQUE

Flood forecasting in Mozambique is the responsibility of the Ministry of Public Works and Housing (MOPH). Within this Ministry, the National Water Directorate (DNA) is designated this task.

The gathering of hydrological data (water levels, discharges and precipitation) is organised by the operational institutions (OI) of the Water Directorate. These are either the Regional Water Authority (ARA in the south and centre of the country) or the hydrometric section of the Provincial Directorates of Public Works and Housing (DPOPH) (north of the Pungué Basin).

Available real-time information

Water levels are registered at hydrometric stations in the river. These stations are constructed along the rivers and consist normally of several staff gauges (0-1.5 metres, 1.5 -3 metres, 3 - 5 metres, up to 11-13 metres) which are mounted perpendicular to the riverbed. Very often a rain gauge is also mounted near the river. Every day, someone paid by the organising institution indicated (known as a leitor), registers the water levels at 07:00, 12:00 and 17:00hrs and the fallen rain at 09:00hrs. In emergency situations, such as floods, levels are registered five times a day, including also the levels at 09:00 and 15:00. The operational institution regularly collects, in normal circumstances, the registered information. For flood forecasting however, these registrations have little or no value because the procedure cannot provide the absolute necessary real-time information.

For flood situations, the water levels and rain data of some key stations are transmitted by longwave VHF radios two or three times per day to the DNA and/or to the OI. Besides this, dam discharges are communicated either by telephone, fax or radio. This is the only real-time data available to the staff involved in the flood forecasting process.

The network of key stations (water level and rainfall) is not very extensive due to lack of maintenance, lack of interest of the OI, as well as lack of resources and equipment (radios). The water levels' data available for flood forecasting is therefore very limited. For example, the Limpopo and the Incomati Rivers have only 3 key stations each; the Buzi and Pungue have only one (recently installed) and the Zambeze River has six key stations with real-time information.

Telemetric systems

A proper alternative for observers reading the water levels could be a telemetric system. A telemetric station consists of an automatic water level registration unit and a transmission unit. The water levels are registered constantly and the mean data value for every certain interval (e.g. 10 seconds, 1 minute, or 10 minutes) is stored in a datalogger. After storage, the transmission unit sends the calculated value regularly to a central operation room by radio or satellite transmission.
The advantages of the system are obvious: having real time data not dependent on human beings. However, unfortunately the system also has some disadvantages as a sophisticated technology: the possibility of theft and lack of data if the system fails. The poor results of the HYCOS pilot project (in Mozambique) and the only other installed system (ARA-Sul - Umbeluzi River) so far proves that a telemetric system is not easy to implement in rural and deserted areas of Southern Africa. This is due to lack of knowledge and capacity of the implementing agency and staff, lack of maintenance and spareparts, theft of equipment and lack of experience.

Available discharge curves

When all data has been collected, it is analysed and converted in order to obtain a forecast for the water levels in the river(s).

Thereafter:

-Obtained real-time water levels have to be converted to discharges.
-Discharges have to be delayed with the travel time and corrected using the correction factor.
-The discharge for a certain station downstream can be converted back to water levels.

The essential discharge curves are generally not available in Mozambique. Discharge curves are the result of regular measurements of discharges at various levels (high and low) of the river. Discharges curves need to be updated every year (horizontally during floods and vertically due to sedimentation or erosion) due to the changes of the riverbed. Unfortunately, for many key stations discharge curves do not exist or are not updated due to the lack of equipment and resources of the DNA and lack of interest of the OI. For most key stations only 'non-updated' curves (from colonial times) or obviously inaccurate curves are used. In the authors' experience, in the majority of cases a valid discharge curve is not used.

Rain data and forecasts

The rain gauge is emptied daily at 09:00 and the number of millimetres of rain is registered on a special form. These forms, like the water levels, are gathered rather irregularly. On rare occasions, the rain gauge data is transmitted by radio. This mostly occurs when the rain gauge is installed near the water level gauges and the information is sent together with the water level.

The rain data is stored in the National Water Database. Although very long series of rainfall exist, none of the data of the Mozambican rain stations has been analysed for the relation between rainfall and discharge of the rivers. This is due to the lack of capable staff, lack of funds to execute studies and moreover, the lack of available discharge data.

As such, the gathered rainfall data of the various stations cannot be directly used for flood forecasting.

Travel times and correction factors

Sometimes travel times can be obtained from existing data and former studies. In general, the hydrologists involved in the flood forecasting are not very experienced in this area, nor do they have profound knowledge of the river basins. For some rivers, very general travel times and correction factors are used which are not based on in depth studies.

PREPARATION OF BULLETINS

The main objective of flood forecasting is the monitoring of the development of the floods in the national rivers, following the development of the floods in the international part of the national rivers and providing adequate information to national institutions. Therefore the available data has to be properly analysed, based on hydrological knowledge and the experience of the hydrologists.

As described above, the information available for flood forecasting is limited. The prediction of river levels downstream based on upstream discharges can be considered important but as the authors experienced during the floods of 2000 and 2001, it is almost impossible in Mozambique.

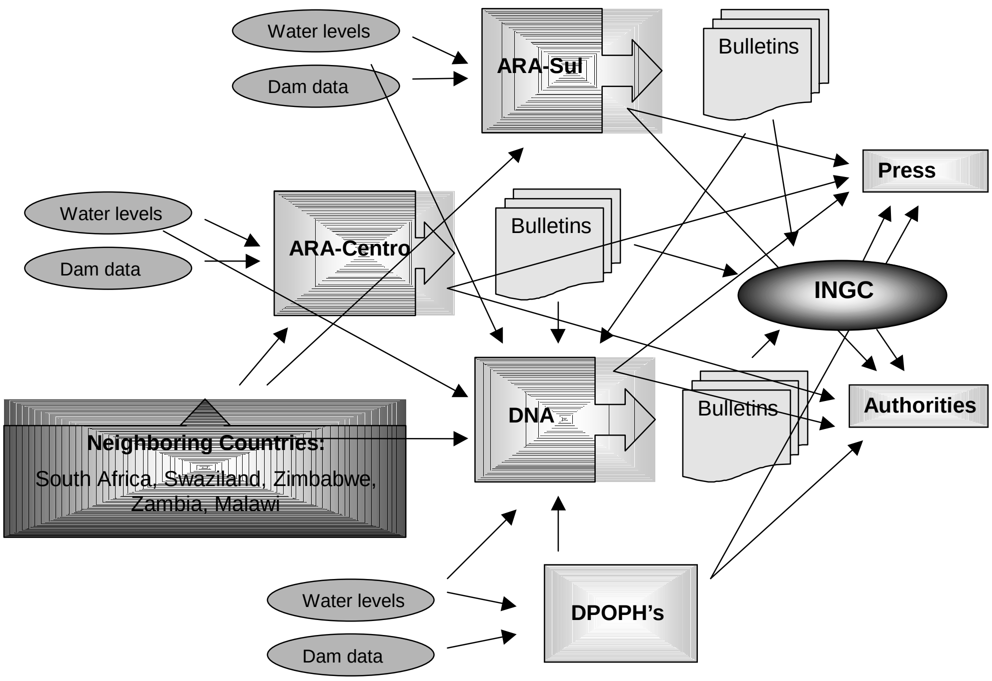
The hydrologists at the responsible authorities (DNA or ARA) prepare a bulletin once a day that consists of tables with water levels at 9:00, 12:00 and 17:00 hrs of the key stations. If possible, the discharges are given, as well as tables with dam levels and discharges. In the summary, the tendency of the water levels of previous days and an expected tendency are described.

All the key stations have an alert level and when the water level is above this value the authorities advise the population in the river basin to move to higher areas. No indication is given as to how many centimetres the water level is above the alert value and in some key stations the alert values are chosen arbitrarily.

The objective of the bulletins is to gather the technical information and send it to the INGC. The INGC should, based on this information, make decisions about warning the population.

DISSEMINATION

In the process of flood forecasting, various institutions and authorities are involved in the supply, gathering, storage and analysis of data: the National Directorate of Water (DNA); the operational institutions (O.I.) for regional water management (ARA-Sul, ARA-Centro and the other established ARAs and Provincial Directorates of Water - DPOPH); the National Institute of Meteorology (INAM); Management Authorities of the various dams not covered by the ARA's (HCB, EDM); Water Authorities of neighbouring countries (South Africa, Zimbabwe, Malawi and Zambia); Meteorological Institutes of neighbouring countries (idem) and Management Authorities of international dams (idem). The information they gather is used by the institutions themselves, but also demanded and used by the National Institute for Disaster Management (INGC); Ministry of Public Works and Housing and the Council of Ministers; Regional, Provincial, District and Local Authorities; National and International Press; enterprises with substantial financial interests in the affected basins and a number of other national and international organisations.



The information flow as practised over the last two years is indicated in the diagram. All the information (national and international) is sent to various authorities and finally gathered in one bulletin (sometimes more) that indicates current water levels and tendencies of the levels. The very technical information (water levels and discharges) from the bulletins is reported in newspapers. The diagram clearly shows that the population is not involved in the process.

Due to lack of clear interpretation of the existing legislation, the tasks and responsibilities of the different institutions with regard to river management are not commonly accepted. This became clear during the last floods of 2000 and 2001. But because of these experiences, a new unit within the DNA will soon be created. This unit will be responsible for disaster management (floods and droughts).

BEING WARNED AND FINALLY VISUALLY CONVINCED

In this section, local people's experience and perspectives on the flood warnings will be described. Information was gained from three sources. Firstly, the authors did a case study in the village of Conhane, Gaza Province. The research contained a qualitative aspect in that two presidents of localities were interviewed as well as several local women and men and a more quantitative aspect involving a questionnaire. The qualitative aspect provided a good basis for formulating a questionnaire, which was distributed among 20 families in Conhane. While interviewing, a number of people usually gathered around us and the interview evolved into a group discussion, providing more views to better understand the situation. However, the questionnaire was completed with answers from the people with whom we started and had randomly chosen. The sample remained small as the interviews turned out to be lengthy because the people really wanted to talk about the floods. Many expressed that they were still afraid but had returned to Conhane because it is their home and their survival depends on their irrigation plots in the scheme.
The second source was an ARPAC report (Simão et al, 2001) in which the results of a large survey about the warning system were analysed. The third source was Christie and Hanlon's book (2001) about the floods in Mozambique. The book provided useful information but remained vague on the sources and content of the warnings.

Conhane village is situated along the road to Chokwe (18 km downstream of Chokwe, see map) in the Limpopo flood plain, in a huge irrigation scheme of 30.000 hectare[2] . Conhane village counts 1162 families with 7311 inhabitants. We asked the inhabitants of Conhane how they received the information about the floods, or how they were warned, in order to assess the most important source of communication and the warning system. We will explore in the next section the content of each warning, but first table 1 depicts the different types of communication sources.

Table 1: The sources of the warning messages (N=20)

President of the locality (government)	85%
Helicopters	80%
Radio	65%
Rescued people who were left by helicopters in C.	60%
A car with a microphone	15%
Neighbours	15%
Newspapers	0
Currandeiras	0
Prophets or dreamers	0
Old people	0

From the above results it is difficult to assess what was the most important source of communication or warning. However, from our interviews, it became evident that a combination of different sources informed people. Simão et al (2001: 3) draws the same conclusion: that people receive the messages in a combined form. They also concluded that radio is the principle vehicle for the transmission of information in the rural areas (ibid). Our interviews did not lead us to the same conclusion, but we wish to point out an interesting sequence that emerged in which the radio takes the lead. In general, the people were initially warned about the floods through the radio. If they proceeded to tell their neighbours who did not own a radio, they were usually branded liars. They then received the warning via the president of the locality, but they did not believe this either and consequently did not act. They resisted or neglected the warnings because, as they said, they had never seen the water that high and found it difficult to believe that it would actually reach the levels described. Only in 1977 were there serious floods and even then they did not have to move. Consequently, they could not believe it. Only when they saw the impressive helicopters landing on

[2] Only one third is actually operational. This is not due to the floods, but the scheme had lost its capacity through the years (salination, no maintenance etc), and at the moment of the floods, the scheme was under rehabilitation .

the road and their pilots warning the people through microphones, did they start to believe the seriousness of the situation, and slowly realise that they had to act. The helicopters left rescued people from the Chokwe area at the road in Conhane, as that was then the closest higher, drier place to the already flooded Chokwe. These rescued people were the ones who formulated serious warnings and the people of Conhane were able to see that they were wet and had been rescued from the floods. This combination of seeing and hearing finally propelled them into action and they grabbed their children and blankets, with no time to pack anything else. Most of them left by foot on Saturday 26th and Sunday 27th February 2000 to Mapapa heading towards the higher dry area, Chiaquelane, 20 to 30 kilometres from Conhane.

The other sources of communication related to flood forecasting all scored zero percent. People explained that newspapers did not reach Conhane, although one young man who participated in our group discussions had read a newspaper in Chokwe which reported that there would be floods. When asked about the importance of the currandeirros (local doctors) or prophets in forecasting the disaster, almost everyone had to smile. No, they said, there are many local healers but not one had foreseen it, not even the prophets. They pointed out that many local healers had also not wanted to believe it and many had lost their divining tools.

On the question of who should be involved in the warning system, the people indicated the following as the most important source:

Table 2: Who or what should be the most important source

The president of the locality (9 of 20):	45%
Government (3 of 20)	15%
Radio and president (3 of 20)	15%
Whatever source, if it is earlier (3 of 20)	15%
Radio (1 of 20)	5%
Nobody can foresee such disaster (1 of 20)	5%

It appears from the above table that the government, through its administrative system of the presidents of localities, is labelled as the outspoken source in the warning system or flood forecasting. Radio was given a much lower priority. However, the president of the locality said that the radio transmitted reliable messages from the meteorological station. He perceived the meteorological station as the only source upon which to rely, his one criticism being that the messages could have been given earlier. However, the people have more faith in their locality president[3]. Hence it seems that people have not lost their credibility in the government, despite the fact that the warnings came late (see below). This may be because they also blame themselves for being slow to act due to their disbelief that the water would reach such high level. Below we look further into this apparent ambiguity. First, more about the content of the warning messages.

THE CONTENT OF THE WARNING MESSAGES

What did the people of Conhane say about the content of the warnings? We will analyse the timing of the warnings in the next section but let us first follow the sequence of the sources as they emerged from the research, namely the radio, the president of the locality, the helicopters and the rescued people.

The president of the locality explained that the message on the radio was very clear and was announced very slowly: “As pessoas que vivem nas areas mais baixas devem tirar se para zonas mais segura” (the people who live in low areas must move to more secure areas). He emphasised that this message had been disseminated on the radio for a whole week before the floods arrived. Unfortunately, he explained, people did not want to believe it because it was the first time and it

[3] The local leaders of the government (see hierarchy below) are perceived as the chiefs. The traditional chiefs have a low profile, which has historical reasons. Frelimo never really want to recognize their existence, and do not attribute them much power (more about this see Bowen, 2000). This is completely different from Zimbabwe where the paramount chiefs are government representatives and headmen and village chiefs receive a salary from the government (see also Vijfhuizen, 1998).

had never happened before. What, then, did the people hear on the radio? Ten of the twenty people indicated that they themselves did not own radio but of those, three had heard the warnings via their neighbours' radio. The thirteen who received the warning via the radio remembered the message as follows:

TABLE 3: Content of radio message

There will be floods and leave (sai) to higher areas	6/13
There will be floods	4/13
The dam is filling up or is full	2/13
Do not remember	1/13

People were of the opinion that the radio message was very clear but they did not want to believe it. In the concluding note we will discuss how to make warning messages or flood forecasting more credible.

What was the content of the message the president of the locality received? He explained that he received the message from the administrative post in Lionde on Saturday 26th February 2000, saying that everyone must leave the lowlands and move to higher areas. The president of the Lionde locality said that the administrative post in Lionde received the information about the floods via the administration in Chokwe. She explained how the Ministry of State administration functions. The president of the country informs the governors of the provinces, who inform the administrators of the districts, who inform the chefs of the administrative posts, who inform the president of the locality, who informs the president of the village, who informs the secretary of a neighbourhood (bairro), who informs the chef of a 'quaterao', who finally informs the chef of a 'bloco' (ten houses). On Saturday 26th February 2000 it was the administrator of Chokwe district who came to inform the administrative post in Lionde. The president of the Lionde locality explained that the administrator informed them they had to leave because the water was very near. She was convinced that the information came in time, and argued "we simply did not want to believe it as we had never seen it. In 1977 there were floods, but we stayed and people could not imagine it would be worse than 1977 in 2000". The State Administration Ministry depicts itself as very hierarchical with top down communication lines. But, of course, many horizontal communication lines also exist. In formal organisations, usually informal groups are formed and horizontal communication lines are an important aspect in the functioning of organisations. In the concluding note we will return to the structural aspects of organisations with regard to the warning system or flood forecasting

What was the content of the warning of the president of the locality to its people? Four of the 20 people did not have an answer, but of the sixteen who did, twelve said that the president said: "sai" (leave). The other four said that the president warned them that they had to take care because the dam and canals were filling up. His message to move came on that very Saturday (26th February) when the president himself was informed that the people had to move. But still, people did not want to believe the message and did not act.

Then the helicopters arrived and were a visible warning. Sixteen said they saw the helicopters and seven of them said that they also received information from the pilots to leave the area because the water was near. One man said that the pilot had a microphone and said "Friends, ladies and gentlemen, we are going to leave this place Conhane. The water has reached two metres already. Don't stay, because in one hour the water will be here". The people who were rescued by the helicopters also warned the inhabitants of Conhane, telling them the water was high and they must leave. It was only when all the warning messages could be verified visually that the people began to leave.

THE AMBIGUITY OF TIMING: WHAT IS EARLY WARNING AND WHAT IS CREDIBLE?

One question which arose was whether the people were informed in time in order to leave their house/area. Sixteen people said that they were informed in time. But the problem was that they did not want to believe it because, as they said, they had never before witnessed it. Therefore, when they did eventually leave they did not have enough time to pack their things. Many complained of having to leave their pots and clothes although thankfully they did take their children and blankets. Several respondents also complained about the lack of transport, which can be regarded as a crucial issue. Even if they had packed their things earlier they would have still had the problem of a lack of transport. Transport was inadequate and that which did exist cost money. One person commented that normally people do not have that amount of money in the house. Those four people who said that they were not informed in time referred to the fact that they lost everything: chickens, ducks, cattle and their stock of food. On the question of how to improve the early warning system, almost everyone said, 'Inform us earlier. We are now going to believe it'. One old woman said, 'We are never again going to resist and neglect. Even if the water is far away, we will pack and go. We are never going to resist again. If we had reacted earlier, we would have been able to take more things. Everybody left at the last moment, the street was full of people'. The president of the locality commented, 'Whatever rains or floods are coming, people are now going to respect it'.

There seems to be a discrepancy here between the response that warnings were in time but unheeded (80%) and the response of having to be informed earlier next time in order to be able to take everything. Whether or not the message was in time, people waited for the visual verification and from now on this visual proof will be strong in their memory.

The president of the locality also raised another important issue. He said that people 'speak false'. 'When the rains come again and we tell the people to move, if the water does not come they will blame us'. Christie and Hanlon also refer to the fear of being wrong (p 125). People in the field, but also those in the meteorological stations, are afraid of being discredited. This seems to have occurred in the El nino predictions of two years ago (see Christie and Hanlon, p 126). However, local predictors for disasters also exist.

Animals as local predictors of disasters:

Apart from radio, the president, helicopters and rescued people, there are also other signs, local ones, which predict or forecast floods or other disasters. Three people (15%) said they were not aware of any, but the other seventeen mentioned several indicators or predictors for disasters.

Table 4: Local predictors for floods/disasters, or local flood forecasting

Local predictors	Number of people who mentioned it
Chihalacavamba	7
Passarinhos brancos	6
Buffaloes	3
Rainbow	2
Frog	1
Flying ants	1
Mwamilambo	1
Water in neighbouring countries	1

Hence only 15% of the total respondents of twenty did not know some local predictors of floods, but others, regardless of age, were aware. They explained that Chihalacavamba is a kind of cagado (tortoise) which falls from the sky. It is not exactly a tortoise, they said, because it has prickles. They emphasised that this is a signal that there is going to be a disaster, for example, a flood or a drought or illness. The animal is always taken to the president of the locality and the Chihalacavamba, which fell from the sky in late 1999, was taken to Chokwe and Chiaquelane. The president of a bairro explained that because the animal has an 'aura', when it falls from the sky a ceremony always takes place and people come and pay money (tribute) to the president of the locality. He explained that the ceremony was held in late 1999, and "therefore we knew that a disaster would come". Hence they were warned by the Chihalacavamba, which emerges as one of the most important local predictors of disasters. White birds, which are also believed to predict

floods, are often mentioned as well. Buffaloes are other remarkable local predictors. A woman, who lived through the floods of 1977 in Massingir, explained that she had seen the buffaloes at that time, so they had been warned. However, she said that she had not seen either the buffaloes or the white birds in 2000. The other respondents also referred to the fact that these local indicators of buffaloes and white birds were absent in 2000.
Mwamilambo refers, according to one woman, to a strong current which is a narrow strip that passes and then returns with floods and cobras. She said that she had heard on the radio that it had occurred in Inhambane. This is presented by Simao et al, (2001, 19) as the most important local indicator as it is the only one to which they refer. They explain that it is a water spirit, symbolised by a cobra which lives at the bottom of the sea. When this cobra leaves for the continent, it brings strong winds and an enormous amount of rain. Their study covers Maputo, Gaza, Inhambane, Sofala and Manica provinces, hence their results may differ from ours. In our study, only one person mentioned this Mwamilambo whereas in Conhane (Gaza Province), the Chihalakavamba was the most prominent local indicator. It is evident that people received some warning in the form of these animals the animals, but still they were not prepared to believe the warnings until they saw the water with their own eyes. In the concluding note we will discuss how these local predictors can be of use in the flood forecasting system. We will also elaborate further on whether technical devices, like dams, may affect whether these animals appear and therefore people's frame of reference in relation to floods.

CONCLUDING NOTE

Flood forecasting in Mozambique has a number of constraints. From a technical point of view, a lack of real-time water levels and discharges, valid discharge curves, elevation maps and additional rainfall data or previsions, results in rather poor flood forecasting.
The bulletins, as prepared by the responsible authorities, are limited to the indication of relative water levels at some key stations. When these levels are above an arbitrary "alert level", a standard phrase indicating that the population should leave the flood plains is included.

Technical improvements, like telemetric networks or hydrological modelling, are still in the very initial stages. Experiences with telemetric networks are, so far, rather poor due to theft, lack of spare parts and maintenance and a lack of proper management.
Hydrological modelling is mostly hindered by the fact that no sufficiently detailed elevation maps are available for the country and that hydrological data needed for calibration and verification of the models do not exist. As such, long and intensive research will be needed before hydrological models can be implemented for flood forecasting.

Parallel to technical improvements, the authors argue for an improvement in the formulation of the message and its communication to the population. The daily bulletins, as prepared by the flood forecasting units, are rather technical and vague. Warnings are given long before life threatening inundation occurs, which causes the population to neglect the messages.

In the current situation, the bulletins are sent to various institutions, including provincial and local authorities, who have to interpret the information and pass it on to the population. These authorities do not have the capacity and resources (e.g. inundation maps) to inform and warn the population properly.

The population is interested in the following:
1) when the flood can be expected
2) the level of it in understandable terms
3) where the nearest, reachable safe havens to are.

On the first point, in the present situation, a maximum accuracy of 12-24 hours can be reached with regard to a known peak. Hydrological modelling and thus intensive hydrometric measurements in the river basins can only improve this.

With regard to the second point, we are convinced that it would be possible to improve the messages by, for example, the inclusion of relevant flood levels of former floods. With this information the “technical” levels become much easier for the population to interpret, as they will be aware of the consequences of the former floods.
With respect to point three, we believe that the main donors should make (military) elevation maps available. When these models are made available to the responsible authorities, safe havens can be located and people can be directed there in cases of emergencies. In addition, adequate transport should also be made available.

Furthermore, the authors are convinced that the current information flow and communication patterns can be improved, resulting in a reduction in the loss of lives. As described above, the flood information reached the population of Conhane but no one acted accordingly. The apparent inappropriate dissemination of the available information relates to the necessity of a clear set of tasks and responsibilities for the authorities. A clear information flow, with indicated bodies interpreting the technical information from Maputo and then informing the population, would improve the credibility of the messages.

Based on this paper, it can be concluded that the content and the dissemination of flood forecasting bulletins must be improved. Firstly, on the technical side, various improvements are suggested including the availability of real-time data, rainfall forecasts, hydrological modelling etc. However, with only a little effort, the dissemination of the information can be improved by the inclusion of (visual) reference levels, safe havens and more accurate time scales.

Besides this, greater attention should be given to local predictors. People in the Zambeze River basin followed the ants to higher areas, and the Chihalacavamba warned the population of Conhane. These predictors might seem scientifically less accurate but the credibility of the predictors is, in some cases, significantly higher than the credibility of flood forecasters.
The fact that the buffaloes and white birds did not appear before the floods can possibly be explained by the construction of dams influencing animal migration patterns.
Perhaps local predictors should be incorporated in flood forecasting, even if helicopters have to substitute the white birds. With regard to flood forecasting, everything should be considered in order to achieve, at least, the credibility accorded to an ant.

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Can Integrated Water Resources Management sustain the provision of ecosystem goods and services?

Graham JEWITT

School of Bioresources Engineering and Environmental Hydrology, University of Natal, South Africa.

jewittg@nu.ac.za

ABSTRACT

Society derives a wide array of important benefits from biodiversity and the ecosystems in which it exists. These ecosystem services are essential to human existence and operate on such an overarching scale, and in such intricate and little-explored ways, that most could not be replaced by technology. Accordingly, approaches to IWRM do not regard the ecosystem as a "user" of water in competition with other users, but as the base from which the resource is derived and upon which development is planned. A goal of IWRM should be to maintain, and whenever necessary, restore ecosystem health and biodiversity.

However, there is a danger that, traditional command and control approaches to management of the water resources system will continue to be applied under the banner of IWRM. Achieving the sustainable use of water resources and thus the maintenance of ecosystem services requires a rediscovery of the hydrological cycle and the water resources system. Such a rediscovery could;

identify characteristics that are critical to the provision of ecosystem services with emphasis on biophysical, economic, social and environmental characteristics and linkages in the system,

provide improved understanding of the behaviour of the interactions of the system, leading to the ability to provide cause and effect predictions and ultimately,

manage the water resources system guided by both biophysical and socio-economic indicators, end-points and value systems applicable to this rediscovery.

In this paper, the concept of an ecosystem approach to the management of water resources is assessed in the light of a reanalysis of the hydrological cycle. The approach to maintenance of ecosystem functioning in South Africa through the so-called Resource Directed Measures is considered in the light of this assessment.

INTRODUCTION

Humans depend on the integrity of natural systems to provide the goods and services they need for survival. In many parts of the world, the limited availability of clean, fresh water is the major constraint to further social and economic development. In arid and semi-arid countries, a burgeoning population, pressing development needs and increasing environmental awareness are rapidly accelerating the demands for water (Kirmani and Le Moigne, 1996). It has been suggested that the rising demand for water and the degradation of its quality, represents the most serious threat to the provision of various goods and services required by society (FAO, 2000). The worldwide movement towards integrated approaches to provide solutions to major problems, including the management of natural resources, such as water, represents a significant shift towards management focussed on the sustained use of these resources. In the water resources field, this shift has found expression in the form of Integrated Water Resources Management (IWRM), most definitions of which identify that IWRM should meet human requirements for the use of freshwater, whilst maintaining hydrological and biological processes and biodiversity which are considered essential for the functioning of ecosystems, the sustainable use of water resources and the maintenance of goods and services provided by them. Worldwide, this is a concept that is being increasingly put into practice and incorporates much of the philosophical framework of "ecosystem management".

However, there is a significant knowledge gap between management practice and the theory and philosophy that has lead to the inclusion of these concepts as policy in South Africa and elsewhere. Consequently, there is a danger that this knowledge gap will result in a misunderstanding of the role of the hydrological cycle in the sustained provision of ecosystem goods and services. For example, approaches to the implementation of IWRM may recognise that aquatic ecosystems are amongst the important users of water, but this tends to divert attention from their role as providers of water resources and other goods and services, with the result that limited recognition is given to the critical importance of these as a basic element of IWRM. In particular, goods and services such as timber or crop production, derived from the movement of water, in the form of water vapour through terrestrial ecosystems are neglected. Thus, there is a danger that ill-considered responses to the rising demand for freshwater could sever ecological connections in the hydrological cycle and alter the quantity, quality, and timing of freshwater supplies on which terrestrial, aquatic, and estuarine ecosystems depend.

The past decade has seen many calls for "better awareness of how the water cycle works, the effect of land uses on the water cycle, the importance of wetlands and other key ecosystems and of how to use water and aquatic resources sustainably" ((IUCN/UNEP/WWF, 1991; Acreman, 2000). In South Africa, water law includes the concept of the Reserve, which is defined as the quantity and assurance of water, as well as the quality of water, which are required to protect basic human needs and to protect aquatic ecosystems in order to secure ecologically sustainable development and utilisation. The so-called Resource Directed Measures attempt to provide for the implementation of the Reserve concept, and some practical methodologies for determination of the quantity and quality of water required to maintain ecosystem functions and services have been developed (Mackay et al., 2000). However, there is has been much debate in hydrological and aquatic science circles about these concepts, and the question "Do we need to rethink our approach to the Reserve?" has been asked. In this paper, the knowledge gap between IWRM policy and practice is explored through analysis of the hydrological cycle, and the approach to maintenance of ecosystem functioning in South Africa through the so-called Resource Directed Measures is considered in the light of this analysis. However, in order to understand these issues more fully, some analysis of the concepts of ecosystem services and sustainability is necessary.

ECOSYSTEM SERVICES AND SUSTAINABILITY

1 ECOSYSTEM SERVICES

Society derives a wide array of important benefits from biodiversity and the ecosystems in which it exists. Ecosystem services are essential to human existence and operate on such an overarching scale, and in such intricate and little-explored ways, that most could not be replaced by technology (Daly, 1999). These services are generated by a complex interplay of natural cycles, powered by solar energy and operating across a wide range of space and time scales, and incorporating both biotic and abiotic components (Figure 1).

These services maintain biodiversity and the production of goods that humans derive from ecosystems, such as seafood, timber and crop production, natural fibres, pharmaceuticals and industrial products. The harvest and trade of these goods are important and familiar parts of the human economy (Daly et al., 2000).

Ecosystem functions can be considered as 'the capacity of natural processes and components of natural or semi-natural systems to provide services and goods that satisfy human needs (directly or indirectly) Generally, ecosystem functions are grouped into four categories (after De Groot

1992): regulation functions, habitat functions, production functions and information functions. The movement of water through the biosphere provides for the production (e.g., crops, timber, cattle), information (e.g., nature experiences, aesthetic information), and regulation (e.g., formation of topsoil, sequestering of CO2, assimilation of nutrients) functions of the environment, as well as the provision of hydraulic habitat in aquatic ecosystems.

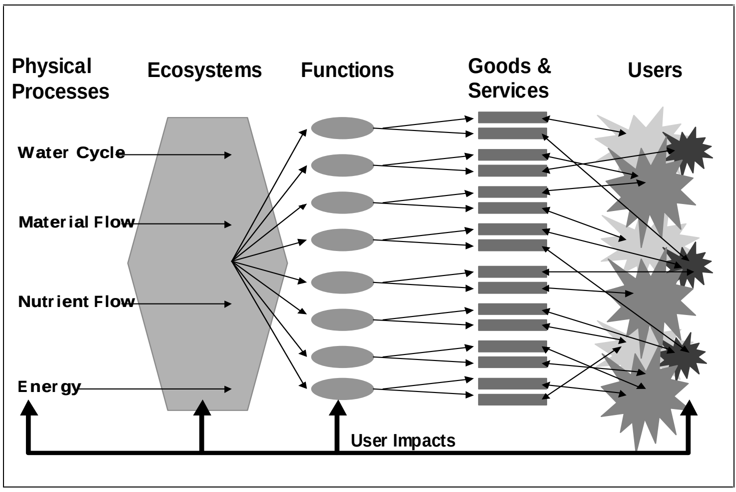

Figure 1 The provision of ecosystem goods and services (after Mander, 1999)

1.1 Sustainability, Sustainable Use and Sustainable Development

Social and economic development necessitates the utilisation of, and thus impact on, natural systems. This modification of natural systems results in a trade-off between the additional (artificial) benefits gained and those which are lost as human adjustment negatively impacts on some natural functions, and this undermines the benefits of natural services provided to society. Where ecosystems are over exploited, their ability to provide these goods and services is lost. Ecosystem approaches to management acknowledge that economic growth and development must take place, but that it should be complementary, rather than antagonistic to environmental protection (Niu et al., 1993). The goal, therefore, is to optimise the mix of benefits to be gained by society from both the natural and artificially derived services provided by harvesting resources from any particular ecosystem (Figure 2)..

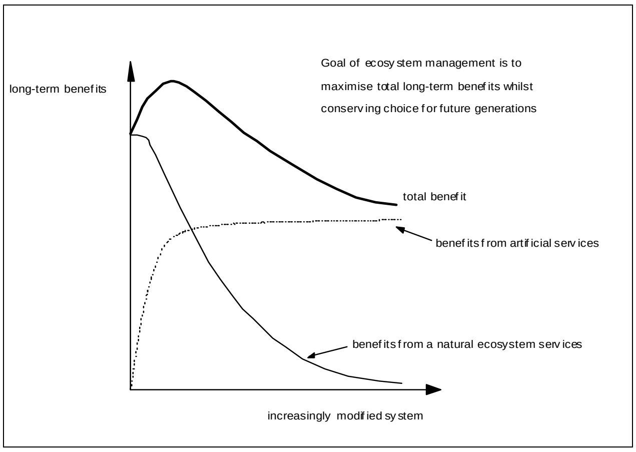

Figure 2 Maximising the provision of goods and services (after McCartney et al., 2000)

Furthermore, the wise re-investment of benefits derived from the utilisation of the ecosystem provides a basis for ongoing sustainability of the resource. However, if the utilisation of the goods and services provided by the ecosystem is purely exploitive, a cycle of unsustainable use may be initiated (Figure 3)

Sustainable development has been defined as, development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland, 1987). Sustainability can be viewed simply as "the ability to maintain something undiminished over some time period" (Lélé and Norgaard 1996), or as an "ongoing endeavour ...rather than a final state that implies the persistence of a system through time" (Sneddon *et al.., 19*96). There are many other definitions of sustainability; however, they almost always share a common theme: that development of a resource should be regulated such that the characteristics, resilience and integrity of the resource in question are protected and maintained within agreed limits.

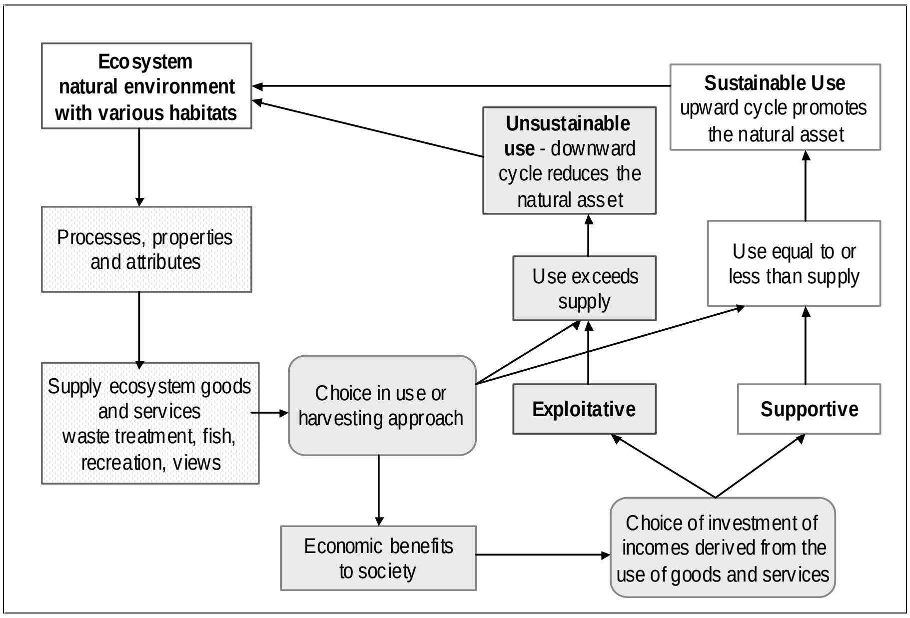

Figure 3 A conceptual framework for sustainable utilisation of natural resources (after Mander, 1999).

The role of resource managers is to implement and devise policies that fulfil the goal of sustainability, thus placing responsibility on the environmental scientist to gather knowledge and produce tools to assist these managers. For many, the principle of sustainability has become a rallying point for the potential resolution of the growing conflicts between environment and economy (Yin and Pierce, 1993) and ecological sustainability has been defined as the intersection of societal values and ecological capacity. It thus reflects, on one hand, the recognition of increasing demands on a finite resource base and potentially rapid changes to the quality of natural resources and, on the other, political necessity to act in response to economic realities (Yin and Pierce, 1993). This implies that cognisance must be taken, in an integrated manner, of the complexities of the biophysical system under consideration and the social aspects they encompass. Water is essential for human survival and a critical component for economic development.

2 AN ECOSYSTEM APPROACH

Current thinking amongst ecologists with regard to achieving sustainability, emphasises the need to conserve biodiversity at multiple scales within a landscape, along with the ecological processes within it and by doing so preserve biodiversity and ensure sustainability. Often, this is described as "ecosystem management". However, the term has generated much debate regarding whether an ecosystem can be managed, and, if it can, what the term "ecosystem management" might mean and "what is an ecosystem?" (e.g. Fitzsimmons, 1996; Jensen et al., 1996). More recently, there appears to be an acceptance that an "ecological approach to management" or an "ecosystem approach to management" are more appropriate terminology (Goodrich, 1996), to describe this way of thinking and to align it with a broader process to mediate resource management so that it integrates ecological, economic and social factors in an equitable way. Despite the initial development of the ecosystem approach as a research paradigm, political level agreements have accepted that an ecosystem approach to management should allow society to harness the functioning of ecosystems and ensure the sustainable use of resources, services and goods that they provide. Ecosystems are highly variable, dynamic and self organising systems (often termed complex adaptive systems) and any management approaches involve dealing with uncertainty. A key aspect of this approach is that the maintenance of diversity in ecosystems builds resilience against large disturbances. The resilience of a system is a measure of the magnitude or scale of disturbance that can be absorbed before the system changes irreversibly in structure, resulting in the permanent loss of the goods and services associated with it. Ecosystem integrity is the term most often used as a measure of “wholeness” and ability to continue to function in a natural way (De leo and Levin, 1997). The integrity of freshwater ecosystems is a function of ecological connectivity operating across a range of spatio-temporal scales.

It has been noted by various researchers that ecosystems operate at many scales, both spatial and temporal. Therefore, an ecosystem approach to management may have a hierarchical context that views smaller ecosystems as nested within increasingly larger ecosystems and that defines the boundaries and scales of ecosystems which should change and evolve in response to both human and natural events (Kay, 1993; USDA, 1996; Haufler et al., 1997). Ecosystems do not have permanent or absolute boundaries and the structure and function of ecosystems change through space and time. Consequently, there is a need to address both spatial and temporal sources of variability and thus diversity, when applying an ecosystem approach to management (USDA, 1996). Multiple factors need to be considered at multiple scales with multiple boundaries.

A single boundary may not capture the relevant areas. Purely ecological patterns for defining useful management areas (ecoregions) may be patchy and discontinuous and often tend to disregard social factors (Voinov and Costanza, 1998). This may hinder the application of management strategies that assume some common public understanding and behaviour. Economic, social and administrative divisions often take no account of ecological and geographical factors and therefore may tend to be unstable and disputable. It has been suggested that catchments (watersheds or river basins) provide an alternative to existing system boundaries, as they may account for both the ecological and socio-economic properties of an area (Reid and Ziemer, 1996; Voinov and Costanza, 1997; Klaphake et al., 2001).

From a temporal scale perspective, short, intermediate and long term considerations need to be taken into account. Many of today's practices only consider short and at best intermediate term availability en reliability of water resources and little attention is paid to the long term sustainability of current practices (McCartney, 2001).

2.1 An Ecosystem Approach to IWRM

IWRM has made its way to the forefront of environmental research very much in conjunction with the concerns about sustainability (Voinov and Costanza, 1997) and the recognition that existing administrative and socio-geographic boundaries are not able to account for both the socio-economic and ecological features of existing systems. The concept of a catchment as a basic management unit, implies certain geographical characteristics, such as topography, that delimit the area not only with respect to water, but also with respect to other media flows, such as energy, material and information. The catchment boundaries may influence local atmospheric transport and local climate, migration flows and the associated patterns of species distribution, as well as dispersion flows of pollution. The flow of water serves as an indicator of the relief and landscape characteristics, on the one hand, and as an integrator of many of the processes occurring within the catchment, on the other. The catchment boundaries may influence local atmospheric transport and local climate, migration flows and the associated patterns of species distribution, as well as dispersion flows of pollution. The quantity and quality of water serves as an indicator of the relief and landscape characteristics, on the one hand, and as an integrator of many of the processes occurring within the catchment, on the other.

The use of the catchment as a management unit may also account for other factors, both of ecological and social origin. Historically human settlements have tended towards sources of water - in southern Africa, these are most often rivers. Consequently, much of the human population and the associated anthropogenic pollution, and other forms of environmental stress are often tied to the river network. The assumption that the catchment offers an optimal spatial scale for the management of ecosystems, may not necessarily be valid, however, it has become accepted that catchments offer a good compromise as a spatial unit on which to focus management strategies.

The hierarchical structure of catchments, sub-catchments and sub-sub-catchments is very useful for upgrading or downgrading scale, “zooming” in and out, changing resolution, depending upon the type and scale of the managerial problems to be resolved. Furthermore, the view of a catchment as a hierarchy of nested sub-catchments is compatible with the view of an ecosystem as a hierarchy of nested smaller ecosystems.

In the past, South African approaches to water resources management have followed a typical command and control type approach where focus has been on controlling the hydrological cycle, largely through construction of dams, in order to harvest its goods and services, and reduce its threats, and thus produce predictable outcomes. It has been noted that this type of top-down approach to management of natural resources inevitably results in a reduction in the natural range of variation of ecosystem properties and processes and a resulting decline in both the services provided, and the resilience of the system (Holling and Meffe, 1996; Rogers *et al.*, 2000).

Furthermore, aspects of the system where quantitative understanding is relatively poor, such as ecological functioning, may have largely been ignored in the decision-making processes. This may have been due no less to the ability of scientists to understand and predict such interactions, than the ability or willingness of policy makers and planners to accommodate ecosystem dynamics, especially, when expressed by non-quantitative means.

The management of water resources solely to maximise consumptive use has been giving way to a realisation that management for environmental values, such as biodiversity, and social and cultural values is necessary (Cortner and Moote, 1994). This is typical of the change in the way that natural resources are now attempted to be managed, a fundamental shift from, in this case, water resources management performed by a single statutory organisation, possibly based on static information from a large systems analysis type of simulation model, to an approach to management that recognizes the importance of the stakeholders, including the environment in the process and the inevitability of change and uncertainty.

In the ecological field, this shift in the management approach found expression in the form of "adaptive management" (Holling, 1978; Walters, 1986) which has been widely advocated as the paradigm which natural resource managers should adopt. It is built on a recognition that ecosystems are complex systems, which are “adaptive”, or “self organising” and that management systems must be able to adapt to change or surprise in the system. In this context management must be both anticipatory and adaptive (Kay, 1997). In South Africa, the legislation of a new NWA in 1998 created an enabling environment for an ecosystem approach to management of water resources. Guidelines being developed for the implementation of the NWA show that adaptive management concepts are becoming embedded in South African water resources management approaches, although some have cautioned that the rush to implement the Act could lead to these principles being compromised (Rogers *et al.*, 2000).

2.2 Ecosystem Services and the Hydrological Cycle

Water is fundamental to life on land as well as in lakes, rivers, and other freshwater habitats. However, renewable freshwater comprises only 0.26% of global water. Traditionally, humans rely on renewable fresh water for drinking, irrigation of crops, and industrial uses as well as the production of fish and waterfowl, transportation, recreation, and waste disposal. Growth in population, increased economic activity and improved standards of living have led to increased competition for and conflicts over this limited fresh-water resource (Gleick, 2000). Often this results in a focus on the development of structures to provide increased volumes of fresh water and other artificial benefits.

This contributes to an argument that our perspective of the hydrological cycle has become typically reductionist, i.e. we have been considering the hydrological cycle purely in terms of simplified representations of mechanical interactions between the components of the system. However, associated with the development of the ecosystem approach, and a focus on the goods and services provided to society from ecosystems, there has been an associated rediscovery of the hydrological cycle.

As water moves downstream through the landscape, it is used along the way to support ecosystems and maintain their functioning. In return for this expenditure of water, the hydrological and biological processes of the ecosystem results in the generation of various goods and functions that may be utilised by communities throughout the catchment (McCartney et al. 2001). In this regard, freshwater ecosystems may be considered as structured, four-dimensional systems in which the spatial patterns of environmental variables and biological populations are determined by longitudinal, lateral, vertical and temporal gradients, interconnected by fluxes of water, energy and materials (**Figure 1**).

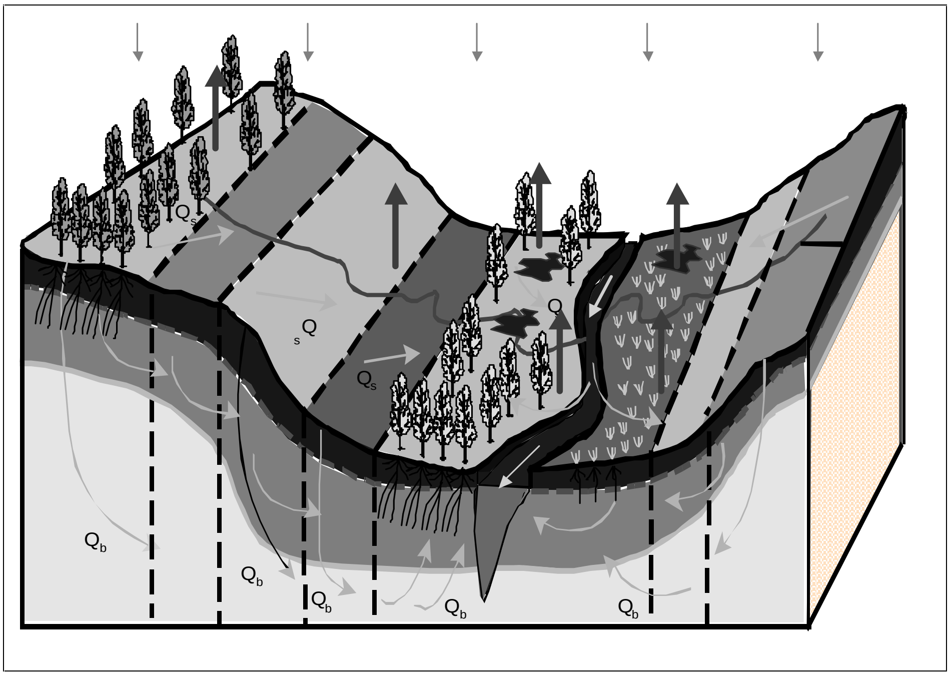

Figure 4 Movement of water through the landscape

When considering the provision of goods and services provided by the hydrological cycle, it is useful to distinguish between movement of water vapour as opposed to liquid water. Recent literature on water and food production often refers to water vapour and liquid water as green water and blue water, respectively Falkenmark *et al*., 1999; FAO, 2000). Blue water is the runoff originating from the partitioning of precipitation at the land surface (forming streamflow) and the partitioning of soil water (forming baseflow and groundwater recharge) (Figure 4). Green water is represented by water vapour and is represented by the flow of water to the atmosphere as evapotranspiration (ET), which includes transpiration by vegetation and evaporation from soil, lakes, and water intercepted by canopy surfaces (Rockström, et al., 1999).

Increasing attention is now being paid to understanding the dynamic inter-relationships between "green" and "blue" water, as these are considered to underpin essential terrestrial and aquatic ecosystem services (Falkenmark *et al*., 1999; FAO, 2000). The FAO suggests that almost all "green" water and a large proportion of "blue" water is needed to sustain ecosystem structures and functions, and maintain sustainable water supplies (FAO, 2000). The movement towards specifying Instream Flow Requirements in many countries arises from the recognition that not all "blue" water should be considered to be available for direct use by society; a proportion must always be reserved for ecosystem functions (Falkenmark *et al.*, 1999; FAO, 2000). Ecosystem services most commonly associated with green water are the production of biomass resulting from the movement of water through agricultural crops and timber by transpiration. Thus, water constitutes an essential building block in all terrestrial production, and also sets the ecohydrological conditions for biological diversity in any habitat (Rockstrom et al, 1999).

The role of land use in the catchment is of critical importance in this regard. The land use in a catchment partitions rainfall between water vapour flows to the atmosphere as evaporation and transpiration (green water), and flow of water to rivers and to groundwater (blue water). Thus, the water passing through a catchment is highly sensitive to its land use and *IWRM must therefore, consider the management of the land portion of the water resources system as critical to its success*. The role of land use and change in land use in a catchment is highly complex. Land use changes may be gradual conversions (e.g. gradual invasion of exotic species) to total modifications (e.g. conversion of grasslands to forest plantation). In addition, there are structural complexities between different land uses, and functional complexities within them, all of which influence the movement of water through the landscape. However, there is often a dichotomy between land use and water resources considerations. Even in important policy documents such as UNCED Agenda 21, sections on land use and freshwater show little appreciation of water related phenomena as determinants of land use, or of land use practices as determining water pathways, water flow and water quality (Falkenmark *et al.*, 1999).

Thus, in the context of this paper, freshwater ecosystems can be considered as linked landscape elements that affect the passage of blue water from the land to the sea and green water from the land to the atmosphere. As such nearly the whole of the terrestrial milieu can be considered as part of freshwater ecosystems. Freshwater ecosystems encompass all the environmental units associated with river catchments, not only the whole length of the river channel, but also lakes, pans, wetlands as well as the upland areas which drain into these - in many instances the river catchment is the most easily identified management unit.

3 SUSTAINING THE RESOURCE BASE

The South African NWA considers aquatic ecosystems to be the base from which resources are derived and without which attaining the goals of equitable access to water and societal development is not possible (DWAF, 1997). Consequently, the water resource has been defined as an ecosystem which includes the physical or structural aquatic habitats (both instream and riparian), the water, the aquatic biota, and the physical, chemical and ecological processes which link habitats, water and biota (Mackay, 2000). This definition is clearly compatible with the ideas proposed by Rockstrom *et al.* (1999) as presented in the preceding section of this document.

The move to integrated management of water resources, on an ecosystem basis has led to the introduction of a new set of tools for water resource management in South Africa. These have been developed according to the concept that there is a degree of utilisation which can be sustained by a water resource before resilience is lost. Resilience in turn depends on maintaining a certain base level of ecological integrity and function. This level is referred to as the “Resource Base” and it is considered that its protection is dependent upon the quantification of a Reserve for the water resource as well as the management of water users in order to meet the Reserve (Mackay, 2000; Mackay, 2001). This approach to water resources protection is based on the development of tools to serve the following:

- Resource Directed Measures that focus on the water resource as an ecosystem and set clear objectives for the desired level of protection of that resource through a classification system, determination of the reserve and setting of resource quality objectives.

- Source directed controls which include a wide range of regulatory measures that are intended to control the sources of impacts on water resources such that the objectives for resource protection are achieved. These include waste standards, licensing of water users such as SFRAs, etc.

- Demand Management initiatives in order to keep utilisation within the limits required for protection.

- Continuous monitoring of the status of the country's water resources to ensure that the Resource Quality Objectives are being met

This is reliant upon the development of methodologies and procedures to achieve these, and is currently a major focus in South Africa. These methodologies should be flexible, protective and should consider extremes, both in socio-economic conditions, and in natural variability of components of the hydrological cycle. In their current state, these can be considered as macro-level approaches to the development of management plans, despite the intention that these will be developed in more detail as the need arises through the identification of priority catchments.

It is in the development of these methodologies that theory and philosophy need to become practice, and it in their design and implementation that addressing the aforementioned gap between these is critical. Recent workshops on the design and implementation of such tools, including RDMs and SFRAs have highlighted some major differences of opinion between scientists, catchment stakeholders and water resource managers (at this stage, represented by DWAF). Clearly, great difficulties are being experienced by the organisations and individuals involved in bridging this gap, with the resulting danger that managers will resort to traditional command and control approaches to management of the water resources system, albeit under the banner of IWRM. This has been referred to as "roll back" by Rogers *et al.* (2000), who also offer some profound recommendations on the complicated issue of implementing the ecosystem approach through adaptive management.

It has been suggested that the proposed resource classification system will create a means of resolving some of these issues by providing for an intersection of ecological and societal values. The classification system will provide for management of the ecosystem based on human (manager, stakeholder, and scientist) judgements as to which ecosystem goods and services, both natural and artificial, should be harvested from those systems. It is to be expected that in the development of this classification system "reasonable people will differ" (Levin, 2001)

One problem of particular concern raised by Rogers *et al.* (2000), is that the protection of the water resource and thus management of the Reserve, could be implemented merely through the control of the number of water use licences granted. They warn that simply limiting the use of water through this type of "command and control" licensing does not constitute an ecosystem approach. This is a valid concern and related to this is the question as to whether to focus on the Reserve and the current Macro Level approach to licensing of water uses, such as SFRAs, will adequately consider the utilisation of green water?

In some regards, the control of commercial afforestation by the erstwhile "Permit System" and the subsequent declaration of forestry as a Streamflow Reduction Activity (SFRA) under the SA National Water Act, could be considered an ecosystem management tool which considers the linkages between terrestrial vapour flows (i.e. transpiration and biomass production by trees) and streamflow. However, the somewhat misleading focus on streamflow in the declaration of SFRAs does little to promote this concept. In early discussions regarding SFRAs, an associated levy known as a "resource conservation charge" was proposed. It is now proposed that this will be implemented as a catchment management charge. Some role-players in the forest industry have called this a "rain tax. However, this is disingenuous – rather, this levy could be considered as an effective way of charging for an ecosystem service (biomass production in forest stands) through estimates of change in ET caused by the transformation from a natural or baseline land use to commercial afforestation i.e. disruption/modification of the natural movement of water from soil to air. In many ways, this is typical of the approach of interest groups who simplify the hydrological cycle to serve their own, often short-term needs. Ongoing research into the water use by agricultural crops (such as sugar cane, maize, wheat etc) and the possibility of them being declared SFRAs is once again focused on their potential impact on streamflows (blue water). However, if one considers the production of biomass in response to the movement of water vapour through these crops as an ecosystem service and that the utilisation of this resource will lead to some degradation of the resource as a whole, then it is fair to consider some re-investment in that resource (Figures 2 and 3). Unfortunately, the debate over SFRAs is clouded by an unfortunate choice of terminology and by political lobbying and deliberate obscuring of the facts for short-term and possibly unsustainable gain.

Perhaps more appropriate to consider as an example of an ecosystem approach is the so-called Working for Water programme of the DWAF. This project involves the systematic reduction of alien invasive vegetation and considers hydrological, ecological and social aspects in its implementation.

Monitoring of the response of components of the aquatic ecosystem to natural and man-induced changes is an imperative of the ecosystem approach. A critical concern is how to most effectively design a monitoring programme for a broad enough range of indicators at adequate spatial temporal scales of biodiversity and ecosystem integrity as a management tool to ensure sustainability of natural resource systems (Rogers and Biggs, 2000). To some extent, monitoring programmes are being devised with adaptive management approach that recognise that the system being monitored is dynamic and variable. Some indicators are selected to represent a wide range of scales, but the focus is on relatively fine scale indicators, such as specific species at specific sites. Furthermore, the indicators selected are largely collected within rivers. Similar to the problem of attempting to sustain ecosystem integrity through the issuing of licenses for water use, "blue water" indicators, including water quality indicators, are an indirect and delayed reflection of catchment condition. Monitoring programmes should also include direct indicators of catchment condition, such as remotely sensed land use assessments.

4 DISCUSSION AND CONCLUSIONS

Considerations of an ecosystem approach to IWRM and the role of the hydrological cycle highlight the dependence upon the movement of water across and between interfaces at a wide range of spatial and temporal scales. Macro level planning does not allow for adequate consideration of processes and linkages at different levels essential for the provision of goods and services which result from effective functioning of the hydrological cycle. "Old style" management of water resources was unable to account for this complexity and often resulted in the loss of ecosystem services which arise from the interactions at these levels.

Furthermore, broad levels of assessment do not consider the implicit hierarchical nature of both ecosystems and the hydrological cycle and the associated understanding that sustainable use of these systems depends adequate functioning at all levels of the hierarchy. The removal of one level will ultimately result in the failure of the system as a whole. It must be accepted that the relationship between the hydrological cycle and the provision of goods and services associated is highly complex and will never be fully understood. Traditional approaches to water resources management have tended to over-simplify the hydrological cycle. Consequently, management options have focussed on the provision of a few of the most obvious of these and the control of the hydrological cycle to provide specific artificial services. This has been exacerbated by the ability of a few powerful stakeholders to influence the decision making process in their favour. Political and social considerations tend to override scientific recommendations, especially where there these are considered to be vague or unquantifiable. Although decision makers and planners need to devote a great deal of effort to ensuring that the system is managed at levels that guarantee optimal exploitation rates (De Leo and Levin, 1997), they must recognise that ultimately, sustainability must "emerge from the democracy of distributed responses and competitive renewal, and not from system-level regulation at constant normative levels" (Levin, 2001).

The movement to IWRM, provides the opportunity to consider the complexity of the hydrological cycle more fully. However, there is a danger that the rush to implement the new NWA in South Africa and the pressure applied by lobby groups, will once again lead to an oversimplification of the hydrological cycle. In particular, there is a danger that IWRM tools will be applied in a such a way that that they will allow a level of degradation beyond that from which the ecosystem is able to recover i.e. beyond the level of its resilience.

Despite the pressure for implementation, it should be remembered that the NWA allows for its implementation in a "phased and progressive" manner. Therefore, institutional capacity building must be an integral part of ecosystem management strategies. Despite the conceptual goal of an holistic management strategy involving all role-players, it is necessary to start in the framework of existing institutions and adopt a pragmatic and at times even piecemeal approach. Scientists and managers involved in enabling the NWA, need to ensure that these structures and tools are consistent with the goal of sustainability.

ACKNOWLEDGEMENTS

The author is the SAPPI Senior Lecturer in Forest Hydrology at the School of Bioresources Engineering and Environmental Hydrology, University of Natal. The support of SAPPI in this regard is gratefully acknowledged. The support of the Water Research Commission and Department of Water Affairs and Forestry is acknowledged with appreciation.

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Economic viability of small-scale irrigation systems in the context of state withdrawal: the Arabie Scheme in the Northern Province of South Africa[1]

Abdul KAMARA [2], Barbara VAN KOPPEN and Litha MAGINGXA

International Water Management Institute (IWMI), 141 Cresswell Street, P. Bag X813, Silverton 0127, Pretoria, South Africa

[2] ab.kamara@cgiar.org

ABSTRACT

The reduction of state presence in irrigation and the transfer of management from government agencies to farmers or farming communities has become a widespread phenomenon, in response to the dual problem of low irrigation performance and constraints to public funding. The underlying principle is to encourage farmers and local communities to take responsibility for the management of local resources, and thereby limit external interventions to the provision information and institutional support services. As most of the schemes in question were not primarily designed for farmer management, experiences worldwide show a mixed picture of positive and negative results. The case of South Africa has recently received attention, as the few pilot schemes, especially in the Northern Province, do not seem to hold much promise of success. Current discussions on the subject raise a lot of issues and hypotheses about the subject of irrigation management transfer to farmers. The paper is an attempt to test some of these hypotheses in the African context, using the Arabie Scheme as a case study.

Key Words: *economic viability; small-scale irrigation; management transfer; South Africa*

1. BACKGROUND

Irrigation Management Transfer (IMT) has gained considerable attention in the last decades, with the broad objective of increasing irrigation performance and reducing constraints on public budget. The process is a strategy to improve economic conditions by reducing the role of the state or it's agents through privatization and empowerment of local communities. The underlying principle of this reorientation is to encourage farmers and local communities to take responsibility for the management of local resources, and thereby limit external interventions to the provision of information and institutional support services that enhance efficient resource allocation.

As evidence of successful IMT worldwide still remains limited especially in the smallholder context (Shah et. al, 2001), the issue has attracted a considerable attention for understanding the conditions of successful IMT (Svendsen, 1992; Vermillion, 1996; Svendsen and Nott, 1997; van Koppen and de Lange, 1999). The case of South Africa has recently received much attention, as most of the schemes in question were not primarily designed for farmer management. Small-scale irrigation schemes – constructed and managed by the state or parastatals – bear a considerable importance in South Africa's political and development history. The dualistic agricultural structure that prevailed during the apartheid era subjected black farmers to subsistence production in the homelands, most of them on government-supported smallholder irrigation schemes[2]. The schemes comprise an estimated 50,000

[1] This paper forms part of the findings of the DFID-funded Project on "Achieving Sustainable Local Management of Irrigation Water in Water Short Basins: South Africa Case Study". The authors extend their sincere gratitude to DFID for the financial sponsorship, and to all those who reviewed preliminary drafts and made various contributions.

[2] Van Zyl et al., (1996) estimate that 89% of arable land in South Africa is allocated to white commercial farmers while less than 13% is allocated to the black majority both for residential and agricultural purposes. A detailed analysis on land tenure in Arabie Olifants Irrigation Scheme is presented in Lahiff, E. (1999).

ha in 202 smallholder schemes with small sizes, many of them about 1 ha or less. Most of the schemes are located in the Northern Province, which is one of the poverty-stricken areas in the country. Initiated in the 1930s and 1950s, most of the schemes are believed to have been constructed without baseline socio-economic surveys or community consultation (Makhura and Mamabolo, 2000). Thus the increasing disenchantment with public support for small-scale irrigation and withdrawal of the operations of the Agricultural and Rural Development Cooperation (ARDC) has left most of the schemes almost dysfunctional[3], which hits hard at rural life in the province, especially in the former homelands.

Typical schemes that are affected by recent withdrawal of state support are the cluster of schemes along the Olifants River, which constitute the Arabie Olifants Irrigation Schemes. The schemes are located on the banks of the Olifants River, getting a large portion of their water supply from the Arabie dam, mostly from pumps or diversion canals from the river immediately downstream of the dam. The schemes consist of about 2,200 ha (in 14 schemes), of plot sizes that are around 1 to 2 ha, and operated by about 1,600 farmers in a mixture of flood, furrow, sprinkler and central pivot irrigation. Some plots are regarded as food plots (vegetable cultivation), but most plots in Arabie were for maize and wheat production, especially for market-oriented wheat production. Since the recent ARDC withdrawal, cultivated area instantaneously dropped by about 50% to 70% in 1997/98 and has continued to what now looks like abandonment by the farmers (van Koppen and De Lange, 1999; Shah et. al, 2001).

2. OBJECTIVES AND ANALYTICAL FRAMEWORK

2.1. Objectives and Hypotheses

The above observations clearly raise a number of questions about the future of the schemes. More importantly, it is of interest to understand the issues that have culminated into this seeming abandonment of the schemes, and to assess whether there is any potential for the farmers to operate the schemes on their own, perhaps with minimal initial support in terms of capacity building, organization and facilitation. There is a need to substantiate whether or not the people are truly interested (and believe in) irrigation farming as a reliable source of income and livelihood. If so, then it is important to assess the role of irrigation in their livelihood strategies. That is, to assess whether or not irrigation farming forms a significant proportion of their incomes to create strong reliance on it as a source of livelihood, or whether it is merely a supplement to other important income sources. While one expects a decline in production to have accompanied the ARDC withdrawal, a complete abandonment is only imaginable if other more remunerate income opportunities or sources are readily available. These assertions are, however, only hypothetical as many other issues such as land tenure security, access to markets and credit, etc., are equally posited as being crucial for the viability of the scheme. Based on IWMI's international experience (Vermillion, 1996; Svendsen and Nott, 1997; Brewer et al.,1999; Shah et al., 2001), we hypothesize that the success of IMT will depend on three broad categories of issues:

- the process of management transfer and how it is accomplished;
- the internal conditions of the irrigation system being transferred (technical conditions, land holdings, reliance on irrigation, heterogeneity, etc.); and
- the presence of institutional support service systems that facilitate integration into the national economic system.

The study is intended to test some of the above hypotheses, highlight factors that affect the viability of the schemes and assess their relative importance. A general framework is developed for analyzing viability but its full application is at this stage constrained by data limitations. Therefore the current study will be limited only to highlighting the current production trends, cost functions and crop budgets, and an estimation of a regression model for a sample of selected schemes. This will form a basis for the design of an in-depth, more data-intensive study that will facilitate a full application of the framework on the entire scheme, which is currently beyond the scope of this paper.

[3] The ARDC is the state supported parastatal that operated all small-scale irrigation schemes in the country. After the change of government in 1994, funding of ARDC activities, which fell in the hands of the provincial governments, posed a big constraint which accelerated the IMT process in the country.

2.2. Conceptual Framework

The concept of viability can be defined at different levels and in various contexts. In a general context, it includes the ability of the scheme to generate sufficient income to satisfy the household income expectations of the irrigators, and to cover basic operational and maintenance (O+M) costs of the irrigation infrastructure, while not mining the natural resources (soil and water). Though income expectations may differ widely across cultures and among individuals, it is much related to the relative role irrigation plays in the income functions of individual irrigators (Shah et al., 2001). Further considerations include the ability of the scheme to maintain cash flows and consistency of income generation over time, and management of risks and shocks associated with small-scale farming. This conceptualization requires a holistic approach, which is depicted in the framework below. The framework is largely developed from IWMI's global studies on the subject (Svendsen, 1992; 1994; Vermillion, 1996; Svendsen and Nott, 1997; Brewer et al.,1999). While most these studies stress on "getting the process right" along with favorable technical, legal and institutional conditions as being crucial for viability, Shah et al. (2001) emphasize that viability after IMT will further depend on the

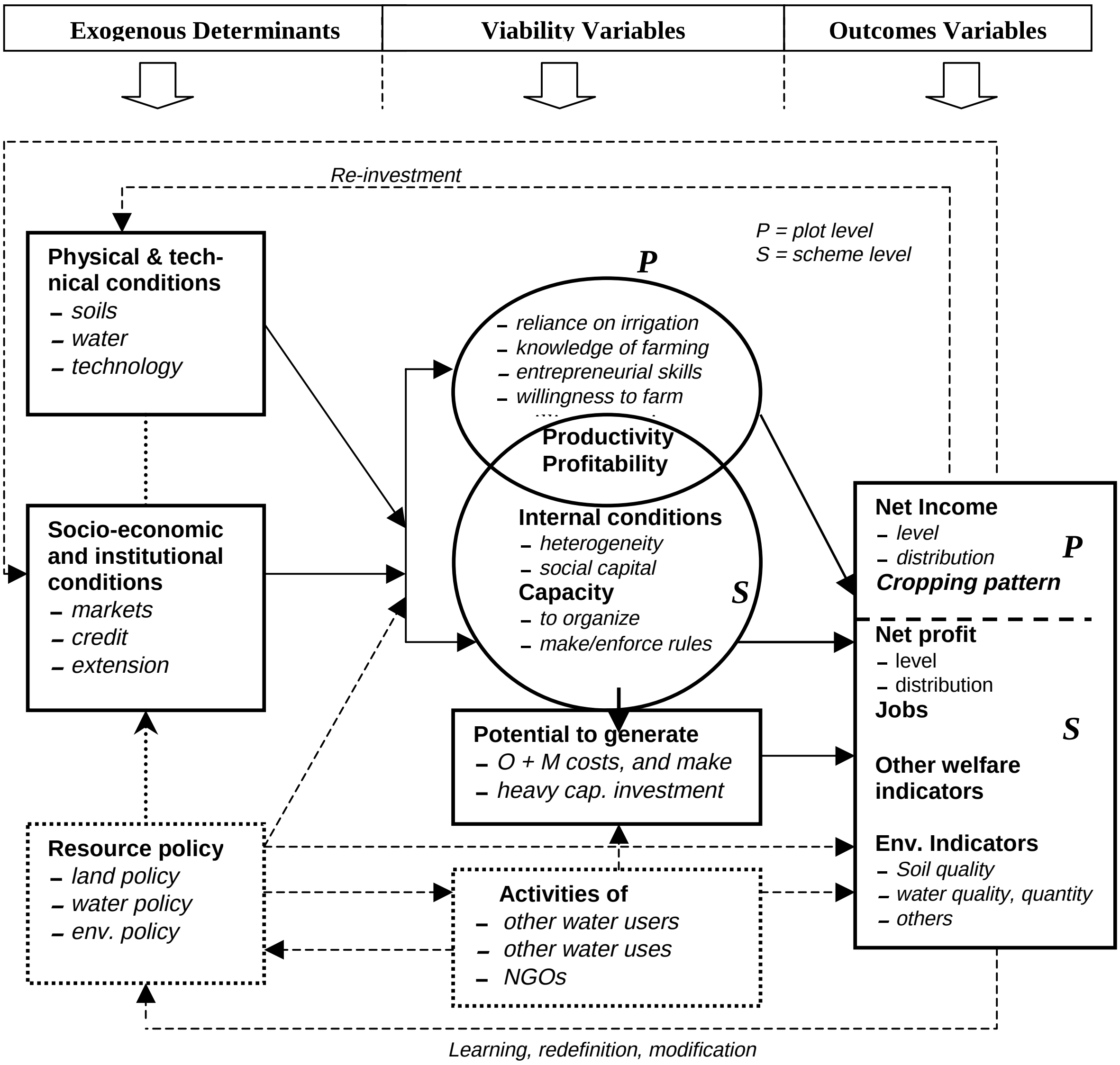

Figure 1: A Framework for Analyzing the Viability of Small-Scale Communal Schemes

costs of sustainable self-management and reliance of the farmers on irrigation. In particular, the authors assert that for the process of IMT to succeed, it must satisfy the following conditions:

- hold out a promise of significant improvement in the life-situations of a significant proportion of the farmers involved in the process;
- irrigation must be central to creating such improvement, i.e. a large proportion of the income of the farmers must come from irrigation;
- the cost of sustainable self-management must be acceptably a small proportion of the improved income; and that
- transaction costs of the proposed organization must be relatively low.

As depicted in the conceptual diagram above (Figure 1), the physical and socio-economic conditions of the scheme must be in harmony with the prevailing water management technology and irrigation system in the context of farmer management. These will influence key viability variables such as productivity and profitability at both the plot and scheme levels. At the plot level, productivity will largely depend on reliance on irrigation as income source, knowledge in farming and entrepreneurial capacity, investment initiatives and other household level variables. The driving hypothesis is that the role of these variables in influencing plot level productivity becomes more significant when the scheme is transferred to farmer management.

At the scheme level, viability will largely depend on the capacity to organize into water use associations, manage the organization, make and force resource use rules and regulations, and resolve emerging conflicts. This capacity is hypothesized to be affected by heterogeneity within the scheme in terms of plot sizes, income sources and social capital variables that enhance meetings and forums for discussing issues related to self-management. These variables will further affect the ability of the scheme to generate management and operational costs, and long-term potential to make heavy investments during periods of shocks. In addition, the activities of other water users such as mines, large scale farmers and NGOs will affect scheme viability, either directly through their production activities, which may affect water quantity and quality, or indirectly through lobbying and social net-working to shift policy variables in their favor. The effect of policy variables such as land policy, water and environmental policy is felt directly or indirectly at all levels of activity, while outcome indicators may lead to policy redefinition through learning and modification. The level and distribution of net income and net profits may result in investments in new technology, and improvements in resource conditions, as well as the provision of institutional and support services (markets, credits, training) that further enhance viability and sustainability of the scheme.

2.3. Data Sources and Analytical Methods

Secondary data were obtained from the ARDC for most of the schemes in Arabie. Due to the inconsistent and incomplete nature of the data, only six schemes[4] were considered in the preliminary analysis of the ARDC data – aggregate crop budgets and estimation of cost functions, net income and gross margins. As the ARDC data did not have any socio-economic component, primary data was collected in two of the six schemes, and intensive surveys further conducted in two of the only three schemes that are currently operational The final analysis was thus conducted with a sample of 64 farmers, selected from four schemes, two of which are completely out of operation since the ARDC withdrawal while two are still operational. Testing the hypotheses developed in the theoretical framework requires various levels of analysis, including regression estimations and production function analysis, benefit-cost analysis, scheme budgeting and linear programming at the whole scheme level. However, the above data only permits the first part of these analyses.

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[4] The six schemes on which the ARDC data was used include: Veeplaats, Gataan (North), De Paarl, Vlakplaats, Vogelstruiskopje and Wonderboom. Intensive primary data was collected on Strydkraal and Krokodilheuvel. Other schemes in Arabie include, Mooiplaats, Haakdoringdraai, Goedverwacht, Nooitgezien, Coetzeesdraai and Hindustan.

3. DATA DEVELOPMENT, RESULTS AND DISCUSSION

The first part of the results presents an overview of production activities and distribution of gross margin across the selected schemes. This is followed by the socio-economic profile of the sample schemes, and the output from the regression analysis.

3.1. Overview of Production Activities in the Arabie Scheme

Table 1 summarizes recent production activities in the selected schemes. During the last few years of ARDC support, only maize and wheat were alternately produced on the schemes in summer and winter respectively[5], which was very much imposed. Production in the last years was rather spontaneous, with a very sharp reduction in area cultivated as well as number of farmers cultivating following the ARDC withdrawal. Aggregate mean yield across the sample schemes are very marginal, with the highest of 5,830 kg/ha for wheat is observed in Vogelstruiskopje (1997), and 4,072 kg/ha for maize observed in Veeplaats (1995/96). While wheat cultivation was virtually abandoned after ARDC withdrawal, maize yields have dropped significantly to about 1,440 kg/ha and 1,804 kg/kg for two of the three schemes that are still active. These results are quite similar to those recently obtained in Hindustan and Coetzeesdraai (Tren and Schur, 2000). Many of the schemes produced at a loss (negative gross margin) even while the ARDC was still in operation especially after the mid-1990s.

Table 1: Recent Crop Production Trends in the Schemes

		Overview of Production Activities Across Selected Schemes (1995 – 2000)							
Scheme	**Year** ***Crop[b]***	***Cultiva-ted Area (ha)***	***No. of Farmers (N)***	***Yield Kg/ha***	***Total harvest (kg)***	***Gross income (R)***	***Total Prod. costs(R)***	***Net income (R)***	***Gross Margin R/ha***
Veepla - ats[a]	1995/w	55 [430]	22 (172)	3,552	195,360	152,907	89,688	63,219	1,149
	95/96/m	275 [430]	106(172)	4,072	1,121,520	795,998	316,069	419,929	1,525
	1996/w	278 [430]	107(172)	3,617	1,006,570	902,691	477,883	424,808	1,525
Gataan (North)	1996/w	42 [75]	35 (180)	4,902	211,760	165,014	43,452	121,562	2,814
	96/97/m	62 [75]	50 (180)	1,850	115,051	75,495	59,043	16,451	265
	1997/w	53 [75]	43 (180)	3,987	209,760	57,320	77,689	79,631	1,514
De Paarl	1996/w	59 [63]	46 (151)	3,054	176,951	37,889	117,489	20,399	352
	96/97/m	55 [63]	45 (151)	897	49,506	32,488	41,679	-9,186	-166
Vlakplaals	1997/w	34 [74]	28 (66)	3,985	135,200	101,400	82,538	18,862	556
Vogelstr.	1997/w	68 [119]	55 (96)	5,830	397,680	298,260	302,108	-3,848	-56
Wonderb.	1997/w	109 [115]	86 (92)	4,439	483,760	362,820	254,654	161,879	1,485
Strydkraal	99/00/m	21* [403]	16[c] (277)	1,806	36,960	46,200	55,152	-8,952	-437
krokodilh.	99/00/m	13* [242]	12[c] (--)	1,440	18,800	18,800	18,797	2.11	0.16

[a] on going peanut, wheat and potato production since early in 2001 by a certain large, white commercial farmer.
[b] wheat is usually grown in winter (May – October) and maize in summer (August – February)
*based on a sample of 16 and 12 farmers respectively; [c] sample only.
( ) = total number of farmers on scheme; [ ] = scheme area; US $ 1.00 = approximately R8.30
[b] *w* and *m* stand for wheat and maize cultivation respectively; N = number of farmers cultivating.

While some of this is attributed to natural disasters such as floods on some schemes (especially in 1996), current gross margins in Strydkraal and Krokodilheuvel seem to be even worse than the ARDC period

[5] Cotton production was introduced in some of the schemes (Veeplaats and Goedverwacht) under contract by LONRHO in 1998/1999 but the program has been long abandoned. In Veeplaats, the entire scheme is currently operated by a certain white commercial farmer under arrangement with the local chief (Kgoshi) but with compensation to some farmers who hold the PTO (permission to occupy) on the land. However, some claim that the process is not legitimate and that they are not receiving anything. Employment of PTO owners as laborers on the farms was also promised. Many are currently working as laborers while others claim to have been dismissed in favor of more productive laborer from elsewhere.

(Table 1). Although local extension agents attribute this to a general under-use of inputs since the ARDC departure, it may also refer to a general lack of interest or care in performing other yield enhancing farm operations, and partly due to high cost of mechanized farm operations such as land preparation which is now in the hands of individuals since the ARDC departed. Although one could expect a reduction in costs during this post-ARDC period due to the disappearance of ARDC's storage, marketing and insurance levies, high ESKOM electricity bills after ARDC departure could also have contributed to a collapse in some schemes. Currently, regulation of water services (distribution, fee collection, etc.) is largely in the hands of the Department of Agriculture through the local extension agents. Fees are only collected for electricity for pumping water on a plots basis – no volumetric charges. Of the three schemes currently in operation, only Strydkraal (sprinklers) and Krokodilheuvel (partly dependent upon pumps) pay water charges. Coetzeesdraai uses flood irrigation and therefore does not pay electricity charges.

3.2. Distribution of Gross Margins Across Schemes

Although most the schemes were generally producing at a loss during the last ARDC days and some are still doing so, the distribution of gross margins across schemes indicates a great diversity among farmers within schemes – some were doing fairly well while other were performing poorly. The same trend is also observed on the schemes that are currently in operation. These trends are highlighted in Table 2.

The level of heterogeneity (in net farm income) is quite high and varies from one scheme to another, and among farmers within a scheme. Nearly all the schemes exhibit coefficients of variation higher than 0.3, which indicate that the distribution of gross margin is highly skewed within each of the schemes. In at least four of the schemes (two of them currently producing), nearly 50% of the farmers produced at a loss (negative gross margins) while others got, on average, R 2,000/ha on the same schemes. This high degree of heterogeneity has serious implications for the formation the proposed water user association (WUAs) or legal entities that will take over the management of the schemes.

Table 2: Distribution of Gross Margins (R/ha) Across Schemes (1995 – 2000)

Scheme	*Year* [b]	*N*	*Min.*	*Max.*	*Mean*	*St. Dev.*	*CV* [a]
Veeplaats	1995/w	22	557	1604	1149	368	0.3207
	95/96/m	106	37	3543	1525	937	0.6144
	1996/w	107	428	2058	1525	489	0.3206
Gataan (North)	1996/w	35	1,146	4345	2814	816	0.2899
	96/97/m	50	-1,026 (22)	3049	265	1139	> 1
	1997/w	43	-1,464 (1)	2479	1514	663	0.4379
De Paarl	1996/w	46	-1,936 (16)	2460	352	1449	> 1
	96/97/m	45	-814 (27)	1859	-166	745	> 1
Vlakplaats	1997/w	28	-2,272 (6)	1950	556	1071	> 1
Vogelstruiskopje	1997/w	55	-3320 (27)	2650	-56	958	> 1
Wonderboom	1997/w	86	-1827 (12)	3445	1485	1211	0.8154
Strydkraal	99/2000/m	16*	-3670 (8)	2784	-437	1828	> 1
Crocodilheuvel	99/2000/m	12*	-1349 (7)	1786	0.162	800	> 1

[a] Coefficient of variation of gross margin among farmers within the scheme; US $ 1.00 = approximately R8.30
[b] w and m stand for wheat and maize cultivation respectively; N = number of farmers cultivating;
( ) = number of farmers with a negative gross margin. * = sample only.

The high heterogeneity (wealth, income levels) gives rise to different incentive structures for investment and preferences for institutions. This may lead to the emergence of interest groups that may influence the formation of the WUAs in their own interest, make the process less transparent, raise the level of transaction costs and increase the chances of failures. This could partly explain why the process of forming legitimate entities to take over the running of the schemes has been complex and is still showing little sign of success in the entire scheme. At the same time, it is relevant to inquire into alternative sources of livelihood for those entirely withdrawing from irrigation, and seek a rational explanation for those who continue to produce at a loss.

3.3. Socio-economic Characteristics of the Sample Farmers

The descriptive statistics indicate a low level of education among the farmers, a majority of whom are old people, with ages of between 53 and 61 (scheme averages), and maximum ages of around 90 years and above. About 56% to over 80% of these farmers (scheme averages)[6] are females with a strong reliance on non-farm income, most of them on pension schemes. Job opportunities in the mines (and perhaps cities) are more suited to men, which could partly be a reason this observation. This high proportion of female farmers may suggest that the future of the scheme is largely in the hands of women, while the dominance of old aged farmers raises critical questions about the future of irrigation farming in the area. For nearly all the households of the sample farmers, non-farm income (pensions, off-farm labor, etc.) by far exceeds farm income. Most of them claim not to be getting any credit, neither do many get support from their migrant husbands and relatives.

In nearly all the schemes surveyed, a considerable percentage of farmers possess livestock (cattle and/or goats), which is particularly important in Krokodilheuvel, Strydkraal and Wonderboom. These observations further support the hypothesis that "on-scheme" irrigation farming may in fact not be playing a very significant role in the income function of many of the farmers. In nearly all the schemes,

Table 3: Descriptive Statistics of Socio-economic Characteristics

Scheme	*Variable*	*Min.*	*Max.*	*Mean*	*Std Dev*
Strydkraal (n = 16)	Age (years)	37	97	61.4	16.6
	HH size	4	16	8,42	3.19
	Education of farmer (yrs)	0	8	2.3	3.03
	Farm income (R)	-4,697	1,960	-1,137	1,931
	Non-farm income (R)	0	7,800	4,010	3,294
Krokodil-heuvel (n = 12)	Age (years)	39	77	61.25	12.0
	HH size	3	15	7.42	3.32
	Education of farmer (yrs)	0	8	2.52	3.32
	Farm income (R)	-843	2,429	0.25	925
	Non-farm income (R)	0	12,960	6,577	4,177
Wonder-boom (n = 25)	Age (years)	23	96	56.48	19
	HH size	3	11	6	2
	Education of farmer (yrs)	0	12	4.2	4.52
	Farm income (R)	749	3,355	2,275	738
	Non-farm income (R)	0	1500	540	666
Veeplaats (n = 11)	Age (years)	37	73	53	15.25
	HH size	2	8	4.18	3.12
	Education of farmer (yrs)	0	10	4.18	1.83
	Farm income (R)	1,255	7,755	4,226	2,130
	Non-farm income (R)	2,400	9,000	6,360	2,166

US $ 1.00 = approximately R8.30

there is some form of spontaneous vegetable gardening along the canals, which they describe as "illegal gardening", which seem to be highly productive. Because every outsider fears that it is illegal, it is difficult to elicit reliable information on this through interviews, even though it was alleged that a majority of the farmers are actually involved in it. To many therefore, this spontaneous vegetable gardening (and home gardening in some schemes) combined with livestock keeping, and currently farm labor for commercial farmers (as in Veeplaats) may have become more attractive than investing in cultivation on the schemes after the withdrawal of ARDC support.

[6] Proportion of female farmers in sample: Strydkraal: 56 %; Wonderboon: 72%; Veeplaats: 73% and Krokodilheu.: 83%.

The issue is also complicated by the land tenure arrangements, which indicate that over 50% of the sample farmers that are currently producing (mostly women) do not have the PTOs (permission to occupy) registered in their name (current sample). The figure is much higher for the entire scheme (van Koppen and de Lange, 1999). Except for widowed females (and exceptional cases), PTOs are mostly registered in the names of males who quite often do not farm but pass the plot to the wife or some third party. Inheritance of PTO, which is possible under the communal property administration, also largely favors males. This situation of women being the actual farmers but titles being mostly in the names of men may also be creating disincentives to farming. Moreover, the situation of the farmers will get more complicated if, for instance, husbands threaten to claim parts of the harvest to which they have contributed nothing but the possession of a mere PTO, or if other PTO owners request for rents for plots in their name but farmed by others.

3.4. Output from the Regression Analysis

To assess the relative importance of the factors discussed so far, an ordinary least square regression model is developed and estimated, with net income per ha being the dependent variable. The model was estimated separately for the two sets of communities covered in the socio-economic surveys,

TABLE 4: Summary of Ordinary Least Square Regression Output[7]

Explanatory Variables	Dependent Variable : Net Income per ha					
	Strydkraal and Krokodilheuvel		*Wonderboom and Veeplaats*		*Pooled Estimates*	
	Coeff.	*t-value*	*Coeff.*	*t-value*	*Coeff.*	*t-value*
Age of farmer (yrs)	-14.527 (15.489)	-0.938	-10.376 (8.226)	-1.261	-4.104 (9.812)	-0.418
Sex (dummy)	78.265 (483.61)	0.162	74.518 (290.24)	0.257	620.756 (332.10)	1.869*
Land Title (dummy)	1124.92 (621.92)	1.809*	-95.924 (258.69)	-0.371	624.72 (346.95)	1.801*
Education of farmer (years)	148.034 (79.780)	1.856*	-74.203 (37.272)	-1.991*	53.230 (46.241)	1.151
Family size	-193.931 (78.279)	-2.477**	39.446 (53.869)	0.732	-150.600 (48.268)	-3.120***
Plot size	603.421 (850.95)	0.709	512.595 (192.59)	2.662**	401.756 (309.63)	1.297
farm income as a % of total income	1.620 (3.430	0.472	22.651 (6.813)	3.324***	9.861 (2.905)	3.394***
% of harvest un-marketed	19.386 (15.843)	1.224	--		--	
Livestock (dummy)	87.796 (501.64)	0.175	-231.908 (255.38)	-0.908	-111.370 (342.64)	-0.325
Observations (N)	28		36		64	
R^2-Adjusted	0.41		0.89		0.56	

*; **; *** significant at 10%, 5% and 1% probability levels respectively.
( ) in parentheses are standard errors; -- variable excluded in equation;

[7] Dummy variables: Sex (1= female, 0 = male); Land title (1 = PTO in farmer's name, 0 = otherwise); Livestock (1 = possessing some livestock, 0 = no livestock).

representing different phases of development of the scheme. These include wheat production in Wonderboom and Veeplaats during the ARDC period, and maize in Strydkraal and Krokodilheuvel in 1999/2000 (post-ARDC). Only maize was produced in the second set of communities in the last years so an assessment of the hypothesized determinants of net income for the same crop (across schemes) was not possible. Also, given that the relative importance of these factors across schemes will vary from year to year, a pooled estimation of the entire data was further conducted in a single analysis. A summary of the estimates is presented in Table 4.

Overall, the results conform largely to the main hypotheses included in the conceptual framework. Most of the explanatory variables carry the expected signs. The important determinants of net income in all the estimations are possession of PTO in farmers name, education, reliance on farm income (farm income as a % of total income of the farmers), and to a lesser extent gender of the farmer. Proportion of farm income positively affects plot level performance. The coefficient is highly significant in two of the estimations while the third estimate also bears the expected sign but remains insignificant. This indicates that those who derive a higher proportion of their income from irrigation put more effort into it to maximize farm income. This is also confirmed by the dummy coefficient for the possession of livestock, which indicates that those with livestock are performing relatively poorly in terms of net income per ha from irrigation. The possession of PTOs in farmer's name is also positively related to net income per ha derived from irrigation. This relation is significant at the 10% probability level in the post-ARDC equation as well as in the pooled estimation, but remains negative and insignificant in the second equation (ARDC period). This may indicate that the possession of PTOs for women farmers has recently gained more significance in terms of incentives for farming than it was during the ARDC period.

In all the estimations, the dummy coefficient for gender, indicate that female farmers do better than males. This conform largely to the proposition (also in previous studies)[8] that women are more genuinely committed to irrigation farming in the Arabie schemes than men, and that the future of the schemes after IMT will largely be with the women. The few male farmers are either retired pensioners or males who lost their jobs in the cities (or could not find one) due to the increasing unemployment in the country. Most of these men are more reliant on their pensions, livestock or other means of subsistence than farming activities on the schemes. As hypothesized, the level of education, which may be related to knowledge in farming has a positive effect on plot level performance. However, the sign of the coefficient is inconsistent and needs further examination. Also, the significantly negative effect of household size on net income per ha requires further attention. One possible explanation is that of high dependency ratios, with most of the households having only one or two adult work force, with many children and old people to care for. It is likely that the migrant young generation (to the mines and cities) leave their children behind with the grand parents. This analysis, however, does not entail exhaustive data on household dynamics to quantify this assertion.

Plot size correlates positively with net income per ha in all the equations but as sizes do not vary much in the current sample (0.84 to 2.5ha), the findings need to be better substantiated in surveys that will entail a wider range of farm sizes. The market access hypothesis could only be tested in the first equation (ARDC marketed for farmers in its days). Market distance could not be used as a proxy as this is fairly uniform for farmers on the same scheme. Appraisal was made of un-marketed maize (which could not be sold) and inserted into the equation but no explicable relationship could be established. This issue also needs to be re-examined.

[8] See e.g. van Koppen and De Lange, 1999; Shah and van Koppen, 1999; Makhura and Mamabolo, 2000; Schreiner and van Koppen, 2000.

4. CONCLUSIONS AND POLICY IMPLICATION

The descriptive statistics reveal a high degree of heterogeneity among the farmers. This is true in terms of many variables especially net income derived from irrigation and non-farm income. This heterogeneity has important implications for the formation of WUAs, common property associations or other legal entities that are expected to take over the management of the schemes. Secondly, the analysis shows that there is a significant relation between having PTOs in farmer's name and plot level performance. The issue of PTOs being in the names of men while the actual farmers are women, which did not seem to be very relevant in the ARDC days (ARDC was the effective entrepreneur), is becoming increasingly important. It is extremely important to assess the number and types of people genuinely interested in irrigation farming on the schemes, and to distinguish these from those who are just "passing the time" or mere pretenders who have other more reliable income sources, but perhaps wanting to capture rents from development assistance by being part of the IMT process. The genuinely interested should be involved in processes of organization, and be vested with membership. Land reallocation at the start of the establishment of the new Water Users Association may be considered.

As noted by other studies (also emphasized in the draft revitalization policy), the issue of market access needs attention as large quantities of maize produced by farmers (especially in Strydkraal) rots away un-marketed, neither do the farmers have the processing technology that makes it readily available for consumption. One female farmer in Strydkraal emphasized that "we would rather leave the product unharvested, than use more labor to harvest and thresh only for it to rot away unsold". Finally, the spontaneous vegetable gardens along the canals, the so called "illegal gardens" need to be assessed for their potential of generating income and improving immediate food security. If vegetable production on the schemes is what the farmers prefer to the traditional maize/wheat rotation, especially on these very small plots, then let is be prioritized.

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Decentralizing water management: an analysis of stakeholder management of water in the Odzi sub-catchment area, Save Catchment Council

Kraspocy KUJINGA

Department of Sociology,University of Zimbabwe, Box MP 167,
Mt Pleasant Harare, Zimbabwe

kraspocy@yahoo.co.uk

ABSTRACT

The paper analyses the process of decentralization of water management to catchment and sub-catchment councils in the Save catchment area in general and Odzi sub-catchment in particular. The paper explores the different challenges being encountered by the new water institutions. The empowerment approach is used to examine the extent to which the formation of the new water institutions is enhancing the empowerment of different stakeholders in the management of water resources. The paper stresses the importance of proper representation of stakeholders on catchment and sub-catchment councils, the need for stakeholder involvement in catchment planning, the importance of financial resources in water management and the need for the government to stop land invasion by ruling party supporters.

***Keywords**: stakeholder/s; empowerment; decision-making autonomy; self-reliance; participatory democracy*

INTRODUCTION

Close to 20 years after achieving national independence in 1980, the Government of Zimbabwe passed two laws aimed at guiding water reform in the country. These were the Water Act [Chapter 20: 24] and the Zimbabwe National Water Authority (ZINWA) Act [Chapter 20: 25]. The aim of the Water Act is to provide for the development and utilisation of Zimbabwe's water resources (Manzungu, 2001). The Water Act of 1998 also established stakeholder institutions, namely, catchment councils (CCs) and sub-catchment councils (SCCs), through whom stakeholders are supposed to be involved in the planning, development and use of water resources. By establishing stakeholder institutions, the Water Act aims at decentralizing water management to the users (WRMS, 2001). The ZINWA Act was meant to establish a national water authority and to provide for its functions (Manzungu, 2001). The Zimbabwe National Water Authority is expected to take over the management of water resources countrywide on a commercial basis as well as to provide technical support to the CCs (Chikozho, 2001). This article analyses stakeholder management of water resources in the Save catchment area in general and the Odzi sub-catchment area in particular.

The formation of multi-stakeholder institutions in the management of natural resources such as water, is a basically a shift from the centralised and state driven natural resources management regimes of the colonial period and the immediate post independence years towards decentralised and mainly community-based management strategy (Nemarundwe and Kodzanayi, 2001). The process of decentralizing natural resources management to stakeholders presents a number of challenges to the new stakeholder institutions. These challenges include proper representation of stakeholders on CCs and SCCs, lack of adequate financial resources, lack of proper catchment and sub-catchment planning, water permit application problems, ensuring that water users pay for the water they are using and political interference in water management. Decentralization can be defined as a process that involves the legal transfer of authority and functions from central government to local institutions to plan and implement development activities and to manage resources at the local level (Manyurureni, 1995:19;). Decentralization is part of the overall thrust toward democratization because of its potential for empowering the public to govern itself (Rothchild, 1994).

The type of decentralization adopted by the government in Zimbabwe in the management of water resources is devolution. The process of devolution involves the creation or strengthening of sub-national institutions whose activities are in large part outside the direct control of the central government (Gasper, 1991:9). Local units or institutions of governance under this form of decentralization are largely autonomous and they constitute legal entities from central government (Manyurureni, 1995:14). Under devolution central government retains residual authority to indirectly control or supervise the activities of such units or institutions as the catchment and sub-catchment councils (Gasper, 1990:19; Makumbe, 1998).

Decentralization of the management of natural resources including water has been adopted in Zimbabwe mainly because excessive centralization of state power and authority has a debilitating effect on good government. It has been argued that decentralization have the potential of resulting in higher levels of participation in decision-making, development planning and implementation (Makumbe, 1998). Thus, decentralization, if properly implemented can lead to the empowerment of different stakeholders in the management of natural resources.

THEORETICAL UNDERPINNINGS

This article uses the empowerment approach to analyse the extent to which the decentralization of the management of water resources is enhancing the empowerment of stakeholders or actors in water management. The empowerment approach helps to analyse the extent to which different stakeholders are involved in the actual decision-making and management of water resources. The ability of CC and SCCs in dealing with the challenges they are facing also demonstrates the level of their empowerment. Friedmann (1992:vii-viii) points out that an empowering approach is one that places emphasis on decision-making autonomy, local self-reliance and direct (participatory) democracy. Thus, decentralisation of any form must have as its end result the enhancement of decision-making autonomy, self-reliance and direct participatory democracy.

Decision-making autonomy refers to a process whereby the local people are able to make crucial choices through their institutions (without much external influence) and control the resources which can assist them in local development (Rowlands, 1996:87). This article examines the extent to which stakeholders represented on the catchment and sub-catchment councils make crucial decisions that enhance better water resources management. For decision-making autonomy to be effective in some instances, institutions must control financial and material resources. It is thus important to see how the new water user institutions have devised strategies to generate income and to acquire certain material resources so that they can fund and undertake water related development projects. The article will also look at the constraints faced by local institutions in trying to exercise their decision-making autonomy as a result of lack of material and financial resources.

Self-reliance refers to a process whereby an individual or an institution develops sufficient analytical, productive and organisational capacity to design and implement its own strategies which can improve the situation of either the individual or the institution and its members (Hartwig, 1999:58). There are several factors that determine the enhancement of self-reliance and these include the power to make decisions, the availability of financial resources and the availability of the right human resources that can help an institution to be productive and to design and implement its strategies. This article analyses the ability of catchment and sub-catchment councils to undertake certain water development projects on their own for the benefit of all stakeholders in their areas.

Viera (1991:17) defines direct (participatory) democracy as a process based on the citizen's real participation in shaping society's projects and benefiting from their results. It is thus important to analyse the extent to which all interested stakeholders in water are participating in water related issues through the CCs and SCCs.

STAKEHOLDER PARTICIPATION IN THE SAVE CC AND ODZI SCC: MYTH OR REALITY

Stakeholders include all those who affect, and/or are affected by the policies, decisions and actions of the system; they include individuals, communities, social groups and institutions (Grimble et al, 1995). Stakeholders that are supposed to be involved in water management in Zimbabwe include Rural District Councils (RDCs), communal farmers, resettlement farmers, small-scale commercial farmers, indigenous commercial farmers, urban authorities, large scale mines, small-scale mines, industry and any other stakeholder group the CC may identify (GoZ, 2000). Prior to the passing of the 1998 Water Act, stakeholder participation in water resources was limited to those with water rights. Most of the communal and resettlement farmers were thus not involved in water resources management as the majority of them did not possess water rights (WRMS, 2001).

The Save catchment area covers three provinces, Manicaland, Mashonaland East and Masvingo. There are seven SCCs in the Save catchment area, namely Odzi, Upper Save, Lower Save, Macheke, Pungwe, Devure and Budzi. The Odzi sub-catchment area is in Manicaland Province and it spans over five districts, Nyanga, Makoni, Mutasa, Mutare and Chimanini Rural Districts. The Save Catchment Council was formed in July 1999[1]. The Odzi SCC was formed on the 8th of July 1999[2]. The formation of SCCs in the Save Catchment area preceded that of the CC. The working group that was chaired by the Manicaland Provincial Administrator, which was responsible for setting up SCCs in the Save catchment area identified stakeholder organisations that would represent stakeholders in water issues on the SCCs and CCs. These stakeholder organisations were advised to present a list of nominations of representatives to the SCCs. The number of representatives for each stakeholder group that was finally agreed for the Odzi SCC was as follows:

Mutare City	1 representative
Redwing Mine	1 representative
Small-scale farmers	1 representative
Forest Industry	2 representatives
Commercial farmers Union (CFU)	2 representatives
Indigenous Commercial Farmers Union (ICFU)	1 representative
Traditional leadership	2 representatives
Irrigators (Small-scale)	2 representatives
Rural District Councils (RDCs)	2 representatives
Zimbabwe Farmers Union (ZFU)	2 representatives
ARDA	1 representative[3]

The stakeholder representatives of the Odzi SCC held elections for the chairperson and the vice-chairpersons on the very same day it (the SCC) was formed. There were three contestants for the chairperson's position, two from the CFU and one from the ZFU. The chairperson of the CFU Eastern

[1] Minutes of the inaugural meeting of the Save CC held at 10.00 HRS on Friday 16th of July 1999 at the Wise Owl Motel, Mutare.
[2] Minutes of the inaugural meeting of the Odzi SCC held on Tuesday 8th July 1999 at Holiday Inn, Mutare.
[3] Minutes of the inaugural meeting of the Odzi SCC held on 8th of July 1999 at Holiday Inn, Mutare.

District at that time won the chairperson's position after polling seven votes[4]. A member of the ZFU became the vice-chairperson since he polled six votes[5]. The other two votes were for the other member of the CFU. It is not clear why two people representing the CFU decided to contest for the position of chairperson of the Odzi SCC. The CFU representative who won the chairperson's position is a former chairperson of a River Board in the Vumba area of Manicaland. The whole exercise of setting up the SCC and electing office bearers was actually done in a hurry[6]. The stakeholder representatives might have been meeting for the first time but were promptly asked to elect office bearers.

The chairperson and the vice-chairperson of each SCC in the Save catchment area automatically became members of the Save CC as required by the law (GoZ, 2000). On the inaugural meeting of the Save CC the councillors elected the chairperson and vice-chairperson of the CC. The position was contested by the chairpersons of Macheke SCC, Odzi SCC and Upper Save SCC. The chairperson of Odzi SCC won the chairperson's position after polling six votes. The chairpersons of Macheke and Upper Save polled 4 votes each. The chairperson of Macheke SCC later won the position of the vice-chairperson after polling 12 votes.

A closer look at the composition of the Odzi SCC shows than the majority of communal and resettlement farmers lack proper representations on these two bodies. Since communal and resettlement farmers do not have proper representation on the Odzi SCC, it also means that they do not have proper representation on the Save CC. This is because of the manner in which the selection of stakeholder representatives on the Odzi SCC and other SCCs was done. The communal and the resettlement farmers are represented by the ZFU on the Odzi SCC and other SCCs in the Save catchment area[7]. This is despite the fact that some of the communal and resettlement farmers are not members of the ZFU. The fact that communal and resettlement farmer need more representatives since they are more in number were not taken into consideration. Moreover one of the ZFU representatives who was elected vice-chairperson was not from the Odzi sub-catchment area. He was in the Manicaland provincial executive of the ZFU. His area of residence is Rusape. This person served on the Odzi SCC from June 2000 to May 2001. He left his position after the Odzi SCC employed him as a training officer. The fact that someone who was not a resident of the Odzi sub-catchment area once represented stakeholders in this sub-catchment area raises a lot of questions about whether real stakeholder representation is taking place in all SCCs. This shows that no proper verification was done at the beginning in order to make sure that all representatives were from the Odzi sub-catchment area.

Information on the operations of the Odzi SCC to all communal and resettlement farmers is channeled through the ZFU structures and those who are not members might not get to know about certain water issues from the CC and SCC. One of the ZFU representatives on the Odzi SCC said it has been difficult for him to go round the SCC area to hold consultations with the people he represents on issues they want discussed by the SCC and CC. The ZFU is unable to provide resources for such an exercise. The only thing he does is to give feedback in their ZFU provincial meetings and advise other ZFU representatives from different districts to pass on the information to members in their districts. Issues that members of the ZFU want raised in the SCC meetings are also passed to the representatives in these meetings. As a result of this there is no constant contact between the grassroots and their SCC representatives.

[4] Minutes of the inaugural meeting of the Save CC held on Friday 16th July at Wise Owl Motel, Mutare.
[5] Minutes of the inaugural meeting of the Odzi SCC held on 8th of July 1999 at Holiday Inn, Mutare.
[6] Interview with the Save CC manager on 18/09/01.
[7] Interview with the Odzi SCC training officer.

Small-scale irrigators are also not properly represented on the Odzi SCC. There are two representatives for small-scale irrigators and both of them are Marange Irrigation Scheme. One of the small-scale irrigator's representatives said he is on the Odzi SCC to represent Marange Irrigation Scheme irrigators only. He said he does not know about the one who should represent the other irrigation schemes that fall within the Odzi sub-catchment area. There are over twenty small-scale irrigation schemes in the Odzi sub-catchment area. As a result of this he has never met people from other schemes to discuss certain issues that can be presented before the Odzi SCC or to give feedback from the meetings. The small-scale irrigator's representatives said they do not know about the stakeholder group that should represent informal irrigators. If the situation about the representation of small-scale irrigators on the Odzi SCC remains as it is, it would therefore mean that other stakeholders are not participating in water management and would remain disempowered.

The Odzi SCC and other SCCs in the Save CC are facing a problem of some stakeholders who are refusing to be part of them. Small-scale irrigators from schemes Mutambara and Nyanyadzi said that they do not want anything to do with SCCs, CC and ZINWA. They said that the whole idea of setting up these structures is to make them pay for water that comes from God. The Nyanyadzi irrigators have since barred the chairperson of their Irrigation Management Committee from attending SCC meetings. They said they are capable of managing their scheme since they are the ones who constructed it. The irrigators in Mutambara and Nyanyadzi accused the government of passing laws such as the Water Act and ZINWA Act without consulting them. Those interviewed said the government now wants them to be part of a process they do not understand. If stakeholders at Nyanyadzi and Mutambara irrigations schemes refuse to participate in CC and SCC activities it then becomes difficult to say that there is real stakeholder participation in water management. It is also difficult to predict the course of action that will be taken by the Save CC and the Odzi SCC so as to make these irrigators participate in water related issues with other stakeholders.

The other issue that is drawing back stakeholder participation on the Odzi SCC is that of constant absenteeism from the monthly meetings by representatives of the forestry industry, mining, RDCs, Mutare City Council and Agriculture Rural Development Authority (ARDA). The representatives of these stakeholders did not attend the September SCC meeting. This has been described by other Odzi sub-catchment councillors as a major drawback since all the above are major stakeholders who should take an active role in the SCC activities. This shows that some stakeholders are treating the issue of water management as not very important to them.

The Odzi SCC meetings are also a cause for concern since most of the time, a few individuals make contributions during discussions. I had an opportunity of attending the September 2001 meeting. Two councillors I asked after the meeting about why they do not make contributions during the meetings said that they were still learning from people from those with experience in water management. If certain individuals dominate discussions and negotiations in stakeholder institutions, the whole issue about stakeholder participation will lose legitimacy (Edmuds and Wollenburg, 2001). All stakeholder representatives must be given the chance and opportunity to contribute freely on all issues in meetings.

CATCHMENT AND SUB-CATCHMENT PLANNING

The development of sub-catchment and catchment outline plans is one of the challenges confronting CCs and SCCs. The Odzi SCC and Save CC have made little progress towards the development of their outline plans. Plans for the catchment and sub-catchment should have inputs from all stakeholders. Stakeholder input in the development of sub-catchment and outline plans is very critical as the plans should be truly representative (Nhidza, 2001). Since the formation of Save CC and SCCs, no consultations have been held so far as a step towards the development of sub-catchment and catchment outline plans. The Odzi SCC does not have a plan of its own which is based on extensive consultation of stakeholders in the sub-catchment areas. One of the ZINWA staff members said the only thing that is there is a list of projects that the SCCs want done in their areas. The issue of an outline plan for the Save Catchment area was first raised in the CC meeting of January 2000.

Each and every CC needs its own outline plan which has to be approved by the Minister of Rural Resources and Water Development. This plan is the one that has to be used in determining the number of water permits that can be granted in each catchment area. At the present moment the Save CC is only giving provisional water permits. The vice-chairperson of the CC said full permits could only be given after the CC has an approved catchment plan. The task to develop a catchment outline plan has been delegated to ZINWA by the Save CC. When the issue of a catchment plan was discussed in a CC meeting on the 24th of August 2001, some of the councillors were not sure about the contents of a catchment plan. One ZINWA staff in the Save catchment area said they are now in the process of developing the plan and they hope to complete it in December 2001. Since the Save CC does not have a catchment plan, former water rights have not yet been changed to water permits. ZINWA and SCCs are charging water users levies based on water rights.

If a catchment plan that does not include the input of all stakeholders right down to the grassroots is developed, the whole issue of stakeholder involvement would have been missed by the Save CC and its SCCs. The Zimbabwe National Water Authority is supposed to only compile the inputs from the stakeholders into the catchment plan not to develop the catchment plan on behalf of the Save CC.

FINANCIAL ISSUES OF SAVE CC AND ODZI SCC

Financial resources constitute the lifeline of stakeholder institutions such as CCs and SCCs. The amount of financial resources at the disposal of the respective stakeholder institution indicates the potential to run its own affairs and the level to which it is independent of central government and other donors (Masuko, 1995:28). The availability of financial resources can in the long run, enhance institutional decision-making, self-reliance and participatory democracy (Friedmann, 1992:vii). Some of the local institutions in Zimbabwe have been severely affected by the policies of ERP to the extent that they are finding it difficult to develop their own independent sources of income within their localities (Kujinga; forthcoming). Catchment and sub-catchment councils have been formed during a difficult economic and political time which makes it difficult for them to develop their own independent sources of income that can enhance self-reliance, decision-making autonomy and participatory democracy.

Though the Save CC was inaugurated in July 1999, it was not able to hold meetings every month as required by the law due to the unavailability of funds for travelling and allowances for the councillors. As a result of lack of funds, no activities related to water development could be undertaken between July 1999 and May 2000. The Ministry of Rural Resources and Water Development and ZINWA are both not able to finance CCs due to their own limited financial positions. The Save CC later own secured funding from the Swedish International Development Agency (SIDA) to sustain its operations and those of SCCs. Though this has been done, there is no guarantee that donor money will sustain the Save CC for a long time. Serious problems will emerge in the event of the donors stop providing money to the Save CC since it does not have its own reliable sources of income.

The Save CC requested for funding from SIDA for two phases, that is, the inception phase and the initial operational phase. The inception phase was intended to get the CCs and SCCs ready for full-scale implementation of their mandate in terms of the law. The Save CC was provided with a total of Z$1 553 000 (US$28 236) for the inception phase by SIDA. The funds provided were used to recruit a training officer and secretary, buy a vehicle, computer, printer, photocopier, two desks and chairs. The other Z$402 360 (US$7 316) was distributed to the seven SCCs[8]. After the completion of the inception phase in June 2000. SIDA has been funding the Save CC and the funding is due to cease in December 2001[9]. The Save CC further requested Z$12 390 345 (US$225 279) for the operational phase which was to last for 18 months, that is, from July 2000 to December 2001[10]. This money was granted and each SCC got its fair share of the funds.

The Odzi SCC got Z$57 480 (US$1 045) from the CC during the inception phase and more funding was made available under the operational phase. Since the operational phase began, most of the money of the Odzi SCC has been used to pay salaries for the sub-catchment manager, training officer, treasurer and metre readers, allowances for the chairperson and vice-chairperson and councillors. Between May and August 2001, the expenditure of Odzi SCC was Z$376 266 (US$6 840.50)[11].. A SCC which does not have a reliable source of income uses this money. On the other hand Odzi SCC managed to collect Z$43 925 (US$798.63) in the form of levies between May and August 2001. If donor money ceases at the end of 2001, SCCs such as Odzi might face extreme difficulties in trying to sustain their operations.

Commercial farmers who had their farms invaded or ear marked for resettlement purposes have stopped paying levies to the Odzi SCC and to ZINWA. Irrigators at Nyanyadzi and Mutambara irrigation schemes have also rejected the issue of paying levies to the SCC and ZINWA outright. The farmers in these areas said no one has a right to charge them for the water they use since it is a God given natural resource. Nyanyadzi irrigators also asked a meeting with the President of Zimbabwe so that they can tell him that water does not belong to him but to God.

All these events are affecting the ability of the Odzi SCC to collect more levies that can help in its day-to-day operations. The Odzi SCC charges levies of Z$5 (US$0.09) per megalitre for abstraction and Z$2 (US$0.04) per megalitre for storage. These charges are the same which used to be charged by the former River Boards in the Odzi sub-catchment[12]. On top of these levies, water users have also to pay ZINWA levy which is Z$40 (US$0.73/megalitre) for abstraction from a river and Z$270 (US$4.90) per megalitre for abstraction from a storage dam.

WATER PERMIT APPLICATION

The process of applying for a water permit is now easier and faster as the applications are made to the CC and not to the Water Court as was the case with water rights under the 1976 Water Act. If one wants to use water from a certain water source he/she is supposed to collect two application forms from ZINWA upon payment of Z$2000.00. Some of the CC councillors complained that this application fee is too high for the communal farmers. One of the forms will be filled in by an AGRITEX official.

[8] Save CC, Inception phase budget proposal, May 2000.
[9] This was said by the chairperson of the Save CC during a meeting of the Odzi SCC on 14/09/011.
[10] Minutes of the Save CC meeting held on 29/09/00 at ZINWA offices.
[11] Odzi SCC quarterly statement for May to August 2001.
[12] Circular by the Odzi SCC chairperson to all water right holders in zones EC1 to EO5, FM1 and FM2.

ZINWA officials will go and inspect the area where the water will be taken and then make their own recommendations. If ZINWA staff approves the methods of abstraction in their report, the applications together with the ZINWA report are referred to the CC which will have the final say.

The Save CC has not been dealing with new application for water permits. The vice chairperson of the CC said they want to first clear the applications that had been lodged with the Water Court before the passing of the 1998 Water Act. The applications for water permits from the Water Court are still coming to ZINWA offices. By September 2001, fifty-seven applications had been referred to the Save CC from the Water Court and 51 of these were approved by the CC. One of the Save CC councillors expressed fear that if they first deal with applications from the water court they might give more permits to white people who had applied to the water court for water rights. The idea of dealing with applications from the water court first has since been overridden by the catchment manager who directed his staff to issue new applicants with provisional water if they approve their applications. By September 2001, ZINWA had received 19 new applications and of these 14 were approved. The catchment manager did the approvals.

The move taken by the catchment manager to override the decision of the CC can be seen as a hindrance to the process of decentralization though the CC should be criticized for dealing applications referred from the water court. There is nothing wrong about granting new application permits. The only problem is that the Water Act of 1998 gives the catchment manager powers to override certain decisions made by the CC such as granting of water permits or extending them without the latter's approval. This might also cause friction between the catchment manager and the CC. Such a friction might difficult to resolve since the catchment manager is not answerable to the CC but to ZINWA (Chikozho, 2001). The Water Act thus tries to empower CCs to grant permits on the one hand but takes away that power with the other hand.

POLITICAL INTERFERENCE IN STAKEHOLDER MANAGEMENT OF WATER

The on going commercial farm invasions by former fighters of the war of liberation and other ruling party supporters have had a negative effect on the management of water by the Odzi SCC and the Save CC. The land invaders settled on farms where there are dams and canals. On a number of farms in the Old Mutare area the land invaders and some resettled farmers have been accused by the Odzi SCC for vandalising canals and using water without paying for it. The chairperson of the Odzi SCC was asked in a meeting on the 14th of September about what form of action to take against the invaders. He replied saying that he was not the President of Zimbabwe. He advised the commercial farmers to report all vandalism of canals and illegal abstraction of water to the police though he said was aware that no action would be taken against the land invaders.

The training officer of the Odzi SCC said that members of the ruling party in some areas have denied him to hold meetings in certain areas as he was suspected of having a political agenda. In Zimunya communal lands, the training officer was asked to go and get a clearance letter from the ZANU PF Manicaland provincial offices. The people in the area are said to be afraid of opposition parties as the parliamentary sit in the area was won by a candidate from the Movement for Democratic Change (MDC) political party. This training officer who has been denied the right to hold meeting in some areas is the one on whom the Odzi SCC is relying on with regards to make people aware of the water reform process and to make them understand the importance of stakeholder participation and paying for water.

If the farm invasions continue, it will be difficult for SCCs and CCs to manage water properly as the invaders might be very difficult to control. Some of the invaders might continue using water without paying for it. This will then affect the ability of SCCs and ZINWA to collect levies. Commercial farmers on the invaded farms might also become reluctant to pay their levies as they will not be sure about what will happen to their farms in future.

DISCUSSION AND CONCLUSION

The need for all stakeholders, particularly the communal and resettlement farmers to participate in decision-making over water management is of paramount importance (Sithole, unpublished). Real stakeholder participation of the communal and resettlement farmers in the management of natural resources such as water reveals the success of any process of decentralizing the management of resources to the users. The fact that there is no proper representation of communal and resettlement farmers on the Odzi SCC and Save CC shows that real democracy in the management of water resources is far from being achieved. The stakeholders that do not have proper representation on new water institutions are thus still far from being empowered.

There is still a great need for awareness to be done so that the rural people understand what stakeholders are and what stakeholder participation is. This should be followed by better methods of choosing SCC stakeholder representatives. The representatives must know the people they represent as well. The case of representatives of small-scale irrigators on the Odzi SCC show that they (the representatives) do not know the stakeholders they are representing on the SCC.

The refusal by stakeholders in Nyanyadzi and Mutambara irrigation schemes to be part of SCCs show that some stakeholders do not understand the need to participate in water management issues under the new system and do not feel the need to participate on an equal footing with other stakeholders. The stakeholder representatives who are no longer attending Odzi SCC meetings might hold a similar belief. These might have their own valid reasons of not attending the meetings. This also raises questions about how the meetings are conducted and the issues discussed in the meetings. Some stakeholders withdraw participation as a form of protest (Edmuds and Wollenburg, 2001). The Odzi SCC has to find out why some stakeholders are withdrawing their participation.

Sub-catchment and catchment planning must begin at the grassroots. The catchment plan must not be the brainchild of ZINWA but of the stakeholders of Save catchment. If all the stakeholders in the different sub-catchment areas are going to contribute to the catchment plan, this will prove to be real participatory democracy and decision-making autonomy (Viera, 1991).

The government of Zimbabwe should be criticized for decentralizing water management to CCs and SCCs without providing the necessary financial and material resources. Decentralizing of functions to institutions such as CCs and SCCs by a government without providing the necessary financial and material resources can be interpreted as shifting problem areas from the center to the local level (Kujinga, forthcoming). One wonders how the government expected CCs and SCCs to function without initial resources. SIDA should be commended for providing funds to the Save CC, which it used for some of its operations and distributed some to the seven SCCs. Donor funding, is going to cease one day. It is now that the Save CC, Odzi SCC and other SCCs have to explore reliable ways of generating income. Self-reliance should be the ultimate goal of these institutions. If self-reliance is achieved by the Save CC and the Odzi SCC, they could also be able to achieve decision-making autonomy and participatory democracy.

The processing and approval of water permits at the catchment level must be seen as a noble idea as the process is now easy and faster. Applications, which are being referred from the water court to the Save CC, must be processed together with new applications. The CC does not know when the water court will stop referring applications to them. New applicants cannot be made to wait for the backlog to be cleared.

The government should stop the on going commercial farm invasions as these will undermine the functions of CCs and SCCs. If the invasions go on unchecked, CCs and SCCs might be rendered useless and powerless in some areas. The invaders can simply view the CCs and SCCs as opposition institutions and can persecute their members.

There is more that still needs to be done to make stakeholder institution a reality. Stakeholders without proper representation on SCCs and CCs must be properly represented. Extensive stakeholder consultations must be done prior to the production of catchment plans. There is a great need for CCs and SCCs to explore ways and strategies of generating income for themselves as donor money can be stopped anytime.

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A preliminary analysis of the groundwater recharge to the Karoo formations, mid-Zambezi basin, Zimbabwe

LARSEN F[1], OWEN, R[2], DAHLIN T[3], MANGEYA P[2].

[1] Dept. of Geology and Geotechnical Engineering, Technical University of Denmark, Building 204, DK 2800, Denmark

[2] University of Zimbabwe, [3]:University of Lund, Sweden.

[1]fll@er.dtu.dk

ABSTRACT

A multi-disciplinary study is being carried out on recharge to the Karoo sandstone aquifer in the western part of Zimbabwe, where recharge is controlled by the presence of a thick, confining basalt layer. The aquifer is geographically extensive, and has been identified throughout the southern part of the mid-Zambezi basin (fig 1). The potential for groundwater abstraction seems to be huge.

The key issues in this part of the study are the extent of the recharge area and the recharge rates. The direct recharge area has previously been considered to be the area of outcrop of Karoo Forest sandstone, before it dips below an impervious basalt cover. However, resistivity profiling shows that the basalt at the basin margin is weathered and fractured, and probably permeable, while the basalt deeper into the basin is fresh, solid and impermeable. Field and laboratory analysis of 22 groundwater samples support this extension of the recharge area to include a large area below the fractured basalt. CO_2 gas pressures, calculated with the code PHREEQC using field measurements of pH and alkalinity, show that below the fractured basalt the groundwater is an open system in contact with atmospheric CO_2. The ^{14}C and nitrate concentrations in this groundwater also indicate that recent infiltration takes place.

The chloride contents of the rainfall and the groundwater in the recharge area have been measured to calculate direct recharge from rainfall. These data indicate that the direct recharge is in the range of 10 to 130 mm/yr, with an average value of 25 mm/yr. Preliminary results of recharge estimate using ^{36}Cl data suggests lower direct infiltration rates, but further studies are needed.

The combination of hydro-chemical, isotopic and geophysical investigations show that the recharge area extends well beyond the sandstone outcrop area, northwards beneath the basalt some 20 km beyond the basalt margin

Keywords: *groundwater; Karoo aquifers; recharge; geophysics; hydrochemistry*

INTRODUCTION

The Karoo sandstone aquifer has, since 1970, been commercially exploited around the town of Nyamandhlovu for irrigation, and in recent years, the aquifer has been considered as a possible additional water source for the city of Bulawayo. Studies on the recharge to the aquifer are now required in order to ensure that the aquifer is not over-exploited and that a sustainable abstraction rate is maintained.

In this paper, some of the ongoing activities regarding assessment of recharge to the aquifer will be presented. The project is a co-operation between the University of Zimbabwe in Harare, the University of Lund in Sweden and the Technical University of Denmark, and the field data have been collected through MSc studies. The project has been funded by SIDA.

The rate of recharge to the Karoo aquifer is an important parameter, which will control the optimum rate of groundwater abstraction from the basin. The two critical factors controlling recharge are 1) the rate of direct recharge by infiltration and percolation into the aquifer system, and 2) the areal extent of over which recharge takes place. These factors are evaluated in this paper. Additional recharge through river bed infiltration is not assessed here.

HYDROGEOLOGY AND GROUNDWATER FLOW IN THE BASIN

The mid-Zambezi Karoo basin occurs in the north-western part of Zimbabwe, extending from the Zambezi river in the north, southwards to the town of Nyamandhlovu, approximately 40 km north of the city of Bulawayo (fig 1).

The mid-Zambezi basin is considered to be a half-graben extensional tectonic basin, with the southern margin being the passive margin, filled by gently shelving sediments, which deepen to the north (Orpen et al. 1989). There is some evidence, based on borehole sediment thickness, that the margin is not entirely passive, and that some faulting occurs.

The 20-60 m thick Upper Forest sandstone is the dominant water-bearing zone in the upper Karoo, and the 20-100 m upper and lower Hwange sandstone units constitute the main aquifer in the lower Karoo. The Forest sandstone is unconfined in a 15 km broad belt in the southern-most part of the basin (fig 1). Just south of the small town of Nyamandhlovu, the sandstone is covered by a confining layer of basalt, which thickens to a maximum of 90 m in the central part of the basin. Karoo sandstones are present in the entire basin, but the groundwater conditions flow system in the northern part of the basin is not known

A piezometric map of the groundwater surface in the study area shows that there is a gradient towards the north-west with a slope of 2.6 ‰ (fig 2). The groundwater is known to be confined towards the north-west, as shown by sub-artesian and flowing artesian conditions which have been observed in a number of boreholes that penetrate through the basalt at Sawmills and other localities.

Given the relatively small groundwater abstraction north of the well fields in the Nyamandhlovu area, the fact that a hydraulic gradient exists shows that a natural flow of groundwater must be taking place towards the north-western parts of the basin, and consequently natural groundwater discharge must occur to the north-west. The groundwater flow can also diverge north of the study area and flow westwards towards Botswana.

Beasley (1983) estimated porosities from densities of a drill core in the Upper Karoo as 9 to 31%, with an average value of 22 %. Based on in-situ tracer tests, Banda et al (1977) estimated the unconfined storage co-efficient as around 4 %.

Several authors have performed pumping tests in the Upper Karoo Sandstone (Beasley 1983; SWECO 1995; Martinelli et al. 1996). Beasley estimated from sieving analyses a hydraulic conductivity of the sand in the range of $6*10^{-7}$ to $6*10^{-5}$ m/sec, and he reports of transmissivities in the range of $5*10^{-5}$ to $4.6*10^{-3}$ m^2/sec. For consistency of the two data sets, flow must take place in a saturated zone with an average thickness of 100 meter. Sweco (1995) estimates a transmissivity of $1*10^{-6}$ m^2/sec from a deep borehole at Sawmills.

GEOPHYSICAL INVESTIGATIONS

A variety of geophysical investigation methods (resistivity, TEM, gravity, HLEM and ground and aerial magnetic surveys) have been used in the study area to try and determine the aquifer geometry. A key method has been multi-electrode resistivity, using an array of 64 electrodes and a multi-core cable connected to a switching control box, which in turn is connected to an Abem terrameter. This method has been used around Sawmills (Glatz and Persson 1999) and around Nyamandhlovu (Andersson and Engman 2000).

Some results are presented here which focus on the Karoo basalt and allow an appreciation of the changing nature of the basalt layer and its probable effect on the groundwater conditions. Two profiles are presented: the first is from the south-eastern part of the study area near the basin margin (line 1); the second (Sawmills 2) is from the north-western part of the study area much further into the Karoo basin, near Sawmills (fig 1).

These first of these two sections show that the basalt near the basin margin is thin, deeply weathered and fractured. It is therefore likely to be permeable and the sandstone aquifer underneath the basalt in such areas is likely to be unconfined and receive direct recharge. The second section further from the basin margins shows that the basalt has become thicker, continuous and relatively fresh. In such localities, the basalt is likely to be impermeable and act as a confining layer (figs 3a and 3b). This interpretation of the geophysical evidence is supported by the presence of artesian wells at Sawmills and further into the basin and by the chemical and isotopic data collected from boreholes in the basin.

GROUNDWATER SAMPLING

During the first field campaign in this study in 1999, groundwater was sampled from 24 boreholes and the depths to the water table were measured. In the field, measurements were made of dissolved oxygen, electrical conductivity and pH in a flow cell, which ensures that degassing does not occur. Dissolved ferrous iron was measured in a field using a HACH 2010 spectrophotometer and alkalinity was determined in the field using the Gran-titration method (Appelo and Postma, 1996).

Samples for analysis of cations and anions were filtered, and the sample for cations analyses was preserved with 1 vol. % 7M nitric acid. The water for analyses of anions was frozen to prevent bacterial reduction of nitrate. Laboratory analyses were done in Lund, Sweden; cations were analysed with optic ICP (Perkin Elmer Optima 3000 DV) and anions analysed with a suppressed ion chromatograph (Idionex DX-100). Tritium was analysed at the University of Waterloo, Canada and the detection limit was 0.8 TU. The ^{14}C content was analysed at the University of Aarhus, and the ^{2}D and ^{18}O at the Geophysical department, University of Copenhagen. ^{36}Cl was done by AMS measurement by direct counting at ETH, Zürich in Switzerland.

Water types. The results of the analyses in 22 boreholes in the Upper Karoo Sandstone shows that the groundwater can be divided into two overall water types, and the chemical compositions of these is given in table 1. The spatial distribution of the defined water types is given in fig 4.

Water type 1

The water type dominates in the investigated region and has a general composition of Ca-HCO_3, with a high Mg content and a neutral pH in the range of 6.6 – 7.7. Calculations with PHREEQC (Parkhurst and Appelo,1999) shows that the water is saturated with respect to calcite ($CaCO_3$), or more likely a low magnesium calcite with the composition $Ca_{(1-x)}Mg_xCO_3$. Dissolution of the low magnesium calcite is given in reaction (I)

(I) $Ca_{(1-x)}Mg_xCO_3 + H^+ \Leftrightarrow (1\text{-}x)\ Ca^{2+} + x\ Mg^{2+} + HCO_3^-$

The produced alkalinity will be in equilibrium with aqueous $CO_{2\ (aq)}$, which again will be in equilibrium with a gaseous $CO_{2\ (g)}$. The overall reaction is given in equation (II).

(II) $CO_{2(g)} + H_2O \Leftrightarrow H^+ + HCO_3^-$

Calculations based on the pH and alkalinity measurements using the computer programme PHREEQC, give values of $CO_{2\ (g)}$ in the range of 1.5-10 * 10^{-3} atm. These values can be compared with the present value in the atmosphere of 0.3 * 10^{-3} atm. and the highest concentration in contact with soil water, which is 30 * 10^{-3} atm. (Appelo and Postma, 1996). Calculated equilibrium in the $CO_{2\ (g)}$ is in the range of 20 to 100 mg/l, and these are comparable with observed values in water type 1, which are from 28 to 98 mg/l. These calculations shows that the dissolution of carbonate minerals has occurred in an open system in contact with atmospheric or soil $CO_{2\ (g)}$.

The groundwater in type 1 contains up to 6.4 mg/l of dissolved oxygen, which is close to saturation in equilibrium with atmospheric oxygen. Nitrate is present in concentrations from 0.8 to 71.9 mg/l, and such high concentrations of nitrate must be derived from nitrogenous fertilizers used on irrigated farm-lands in the recharge area, which indicates that nitrate can be used as a tracer in this study area.

The silica content in water type 1 samples is relatively high with concentrations from 15.1 to 35.3 mg/l (Table 1). Calculations with PHREEQC indicate that the water is sub-saturated with respect to quartz and other silica minerals in the sandstone. In a groundwater sample collected in the covering basalt layer, the concentration of silica is also high with a value of 28.9 mg/l (Aspelin and Wallin, 2000).

In water type 1, the concentrations of modern C–14 are high with percentages of modern carbon in the range of 74-94 pmc, excluding borehole N1 with 37 pmc, indicating that mixing with old water is taking place in this borehole. The concentrations of tritium are below the detection value of 0.8 TU, again apart the value from borehole N1, which contained 0.9 TU.

Water type 1 is found in the southern-most part of the study site, from areas in the south where the Upper Karoo sandstone outcrops, and extending northwards some 10 to 20 km into the areas where basalt overlies the sandstone (fig 4).

Water type 2

The groundwater defined as water type 2 is a Na-HCO_3 type water. The high sodium content between 87.3 and 154.9 mg/l together with the very low calcium and magnesium concentrations below 1 mg/l and the high pH values between 9.1 and 9.4 shows that the dominant process is a cation exchange reaction, see reaction (III).

(III) $\quad Na\text{-}X + 0.5\ Ca^{2+} = Na^{+} + 0.5\ Ca\text{-}X_2$

where X indicates the sediment exchanger. Calcium is taken up from water to the exchanger, and sodium is released. The water type thus changes from a Ca-HCO_3 type to a Na-HCO_3 type. The source of the sodium on the exchanger comes from the weathering of minerals. eg. albite ($NaAlSi_3O_8$) in the sandstone.

The exchange reaction will have an effect on the pH of the water since the removal of calcium from the water will enhance the dissolution of calcite (reaction I), which consumes H^+, and therefore the pH will rise. In water type 2, pH values are 9.1-9.4 (table 1).

Calculations using pH and alkalinity measurements with PHREEQC gives values of $CO_{2\ (g)}$ in the range of $0.2 * 10^{-5}$ to $3.7 * 10^{-5}$ atm., values which show that the water is not in contact with the atmosphere, as used $CO_{2\ (g)}$ is not replenished.

In water type 2, dissolved oxygen concentrations are in the range of 0.2 – 2.2 mg/l and concentrations of nitrate are from 0 to 1.4 mg/l.

High concentrations of fluoride, up to 5.3 mg/l, are present in this water and these high concentrations of fluoride are associated with elevated concentrations of sulphate, with values up to 266.9 mg/l. These elevated concentrations are found in strata in the uppermost part of the Upper Karoo sandstone, and are most likely associated with dissolution of salt-pans with fluorine and sulphate containing minerals such as fluorite (CaF_2) and anhydrite ($CaSO_4$).

The silica content in water type 2 is relatively low with concentrations from 6.2 to 10.0 mg/l (Table 1). Calculations with PHREEQC indicate that the water is saturated with respect to quartz and other silica minerals in the sandstone.

Concentrations of modern ^{14}C are low in water type 2 with concentrations from 0.04 to 4.9 pmc, and concentrations of tritium are below the detection limit of 0.8 TU.

Water type 2 is found in the northern part of the study area, in the upper Karoo sandstone below the confining layer of basalt (fig 4).

RECHARGE ESTIMATES FROM CHLORIDE CONCENTRATIONS

Estimation of the recharge to an aquifer can be done using the stable chloride isotopes, ^{35}Cl and ^{37}Cl, if it is assumed that the concentration of chloride in the shallow groundwater is due to a further concentration of the chloride in rainwater (Edmunds et al. 1990). Infiltration to the Karoo sandstone occurs most likely both as direct recharge from precipitation and as indirect recharge due to infiltration from stream-beds. The mean annual precipitation in the Nyamandhlovu area is around 550 mm (Beasley, 1983).

The total deposition of chloride in western Zimbabwe, including both wet and dry deposit is approximately 0.5 mg/l, but the figure is not well constrained. Concentrations of chloride in groundwater in the recharge area of the Karoo sandstone (Water Type 1) are in the range of 2.1 to 25.8 mg/l, with an average concentration of 10 mg/l. During this year (2001) sampling of groundwater from 15 shallow boreholes in the recharge area revealed concentrations in the groundwater range from 1.6 mg/l to 76.5 mg/l, and the average chloride concentration was again 10 mg/l. One sample from the Khami River contained chloride in a concentration of 72.7 mg/l.

The observed very low concentration of chloride of 1.6 mg/l most likely represents indirect infiltration from a river-bed by storm-water run-off, while the high concentration may be a result of indirect infiltration from ponds, which have experienced evaporation in the dry season. The intermediate chloride concentrations, with an average of 10 mg/l, may then reflect direct infiltration to groundwater. Assuming that the concentration of chloride in the shallow groundwater is due to evaporation of a rainwater of 550 mm before it percolates below the effective depth of evaporation and subsequently increases in concentration in the soils in the recharge zone, values of the direct infiltration can be calculated to be in the range of 10 to 130 mm per year, with an average value of 25 mm per year.

Measurement of ^{36}Cl contents in recharge waters can also be used to estimate recharge to aquifers, if the fall out of produced ^{36}Cl in the atmosphere is well known and the epigenic production is insignificant (Clark and Fritz, 1997). The natural atmospheric fall out of ^{36}Cl is a function of the latitude (Bentley et al. 1986), and in Zimbabwe, located at 20^{o} south, the fallout is 2.5*10^{8} atoms/m^{2}/yr. However, following marine thermonuclear tests in the period 1952-58, the atmospheric fall out of ^{36}Cl was increased by a up to 500 times greater than the natural level (Andrews and Fontes, 1992).

In the field campaign in 1999, water samples for ^{36}Cl analysis were sampled from four boreholes; S21, S25, S26 and S27 (table 1). Only borehole S21 is located in the recharge area (Type 1), and the other three is located in the confined part of the aquifer (Type 2). In S21 the measured concentrations of ^{36}Cl is 10*10^{7} atoms per litre. With a pre-thermonuclear ^{36}Cl concentrations of 2.5*10^{8} atoms/m^{2}/yr (Bentley et al. 1986), a concentration of ^{36}Cl in this range can be obtained with an infiltration of 2.5 mm from a rainfall of 550 mm. If, on the other hand, the infiltration occurred after the thermonuclear testing was started in 1952, a ^{36}Cl concentration of 10^{7} atoms/litre can also be created with an infiltration of 25 mm, if the fall out was increased by a factor of 10 (Table 2).

If the groundwater in the sample from S21 infiltrated in the period after thermonuclear testing was initiated in 1952, elevated concentrations of tritium should be expected in the water, which is not seen (table 1). Again, on the other hand, the concentration of nitrate of 22.4 mg/l in this groundwater sample clearly suggest that the water is relatively young, as only the modern use of fertilisers with a high concentration of nitrate seems to be able to generate such concentrations of nitrate in the groundwater.

Clearly the potential for the use of ^{36}Cl concentrations in groundwater cannot be evaluated on one analysis alone, and more data must therefore be collected.

	Fall-out ^{36}Cl *10^{8} [atoms/m^{2}/yr]	Infiltration 50 mm	25 mm	2.5 mm
		^{36}Cl atoms/litre *10^{7}		
Pre-thermonuclear	2.5	0.5	1	10
Thermonuclear (low)	25	5	10	100
Thermonuclear (high)	1250	625	1250	3125

Table 2. *Calculated concentrations of ^{36}Cl in groundwater in the Karro Sandstone Aquifer for given rates of evaporation loss. A rainfall of 550 mm per year is used (Beasley 1983). The natural ^{36}Cl fall out concentration is taken from Bentley et. al. (1980), and thermonuclear values are from Clark and Fritz, 1997).*

DISCUSSION AND CONCLUSIONS

The results of the geophysical survey using the CVES method and the chemical composition of the distribution of groundwater types in Karoo sandstone shows that recharge occurs in the unconfined part of the aquifer and in the fractured part of the covering basalt layer in the southern part of the basin. In the studied area this means that the area where recharge takes place is not around 1000 km^{2} as stated earlier (Martinelli et al. 1996) but rather 3000-4000 km^{2}. The total recharge to the aquifer most therefore have been under estimated in the Martinelli (1996) study. Even this expanded recharge area is an underestimate since it does not account for recharge areas to the west along the southern boundary of the basin or recharge areas to the north along the eastern boundary of the basin.

The estimated annually recharge to the Karoo sandstone of 20-25 mm must be confirmed with numerical modelling of the natural groundwater flow generated by the observed hydraulic gradient. However, the Karoo sandstone must be considered as a double porosity medium, where groundwater flow may or may not be significant in the matrix of the sandstone. Therefore an analysis of the hydraulic behaviour of this dual porosity system must be undertaken before a realistic model can be established. Calibration and validation of such a model will, however, be difficult since the boundary conditions are poorly defined. Therefore dating of the groundwater using methods such as ^{13}C, ^{36}Cl and ^{4}He can be useful, but this model must take into account that any decrease in the radio nuclide compounds may not be due to a radioactive decay alone, but also due to diffusion into the matrix of the Karoo sandstone (Neretnieks, 1980; Sandford, 1997).

Based on a recharge area of 3000 km^2, and a recharge rate of 20 mm/yr, a total annual recharge to the aquifer is estimated as $6*10^7$ m^3/yr, which provides approx. 160,000 m^3/day. The present pumping rate from the aquifer is approx. 25,000 m^3/day for agriculture and approx 20,000 m^3/day for the city of Bulawayo. It therefore appears that there is considerable room for expansion of the total pumping rate from the aquifer, but care should be taken to spread the well-fields across the aquifer in order to avoid excessive drawdown in any single locality.

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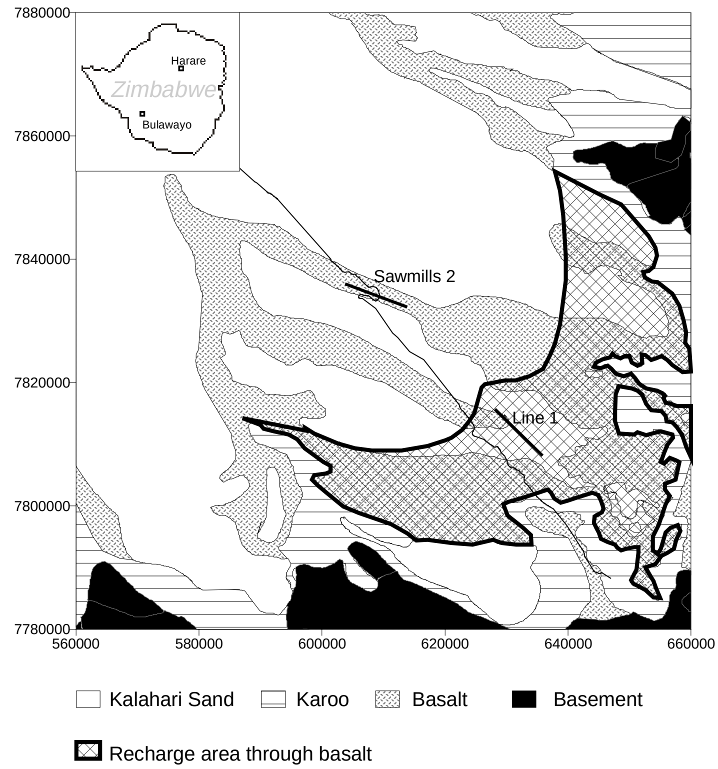

Figure 1: Geology of the study area, showing the extended recharge zone through the basalts near the basin margin.

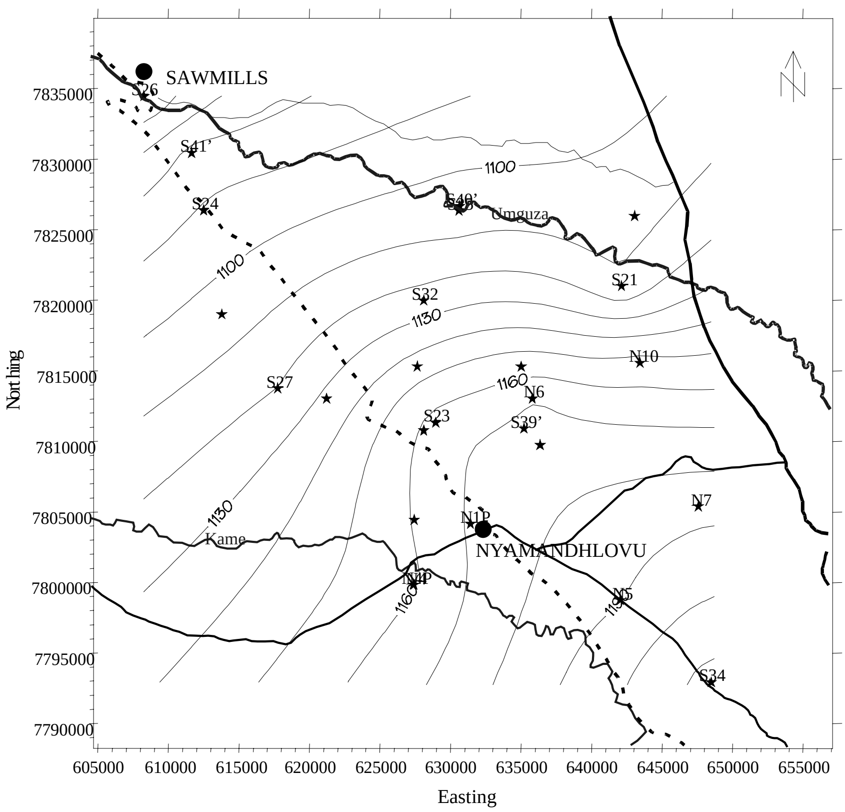

Figure 2. The hydraulic potential in meter above sea level in the Upper Karoo Sandstone based on measurements of the static water table in 21 boreholes during November 1999.

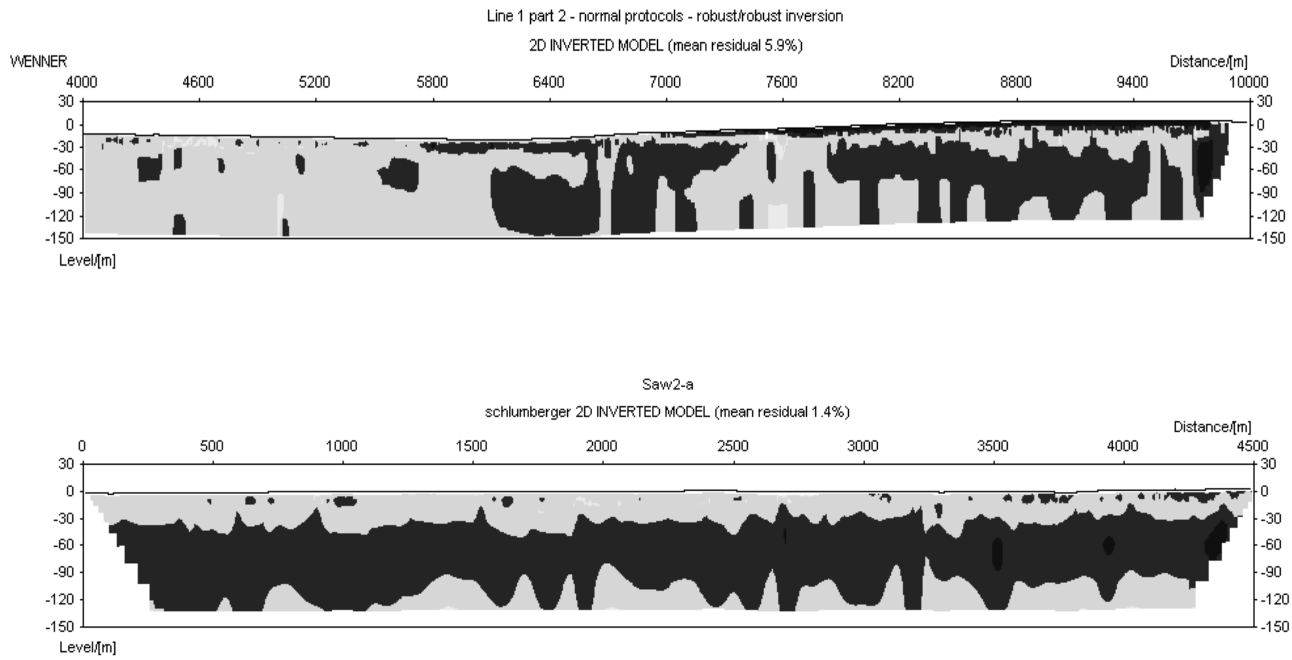

Figure 3a (top) and 3b (bottom).
The two resistivity plots (4x vertical exaggeration) show the extent of fresh basalt, which acts as a confining layer to the Karoo Forest sandstone, which lies below. The light colours are resistivity values below 100 Ωm and the black colour represents resistivity values above 100 Ωm. The upper image is taken at Epping Forest farm, nearer the passive margin of the aquifer to the south-west, and here it can be seen that the fresh basalt is very patchily developed, and is fractured, allowing groundwater recharge. The lower image, taken from Sawmills, shows that the fresh basalt is thick and unbroken here, and hence acts as an impervious layer, resulting in confined conditions in the underlying aquifer.

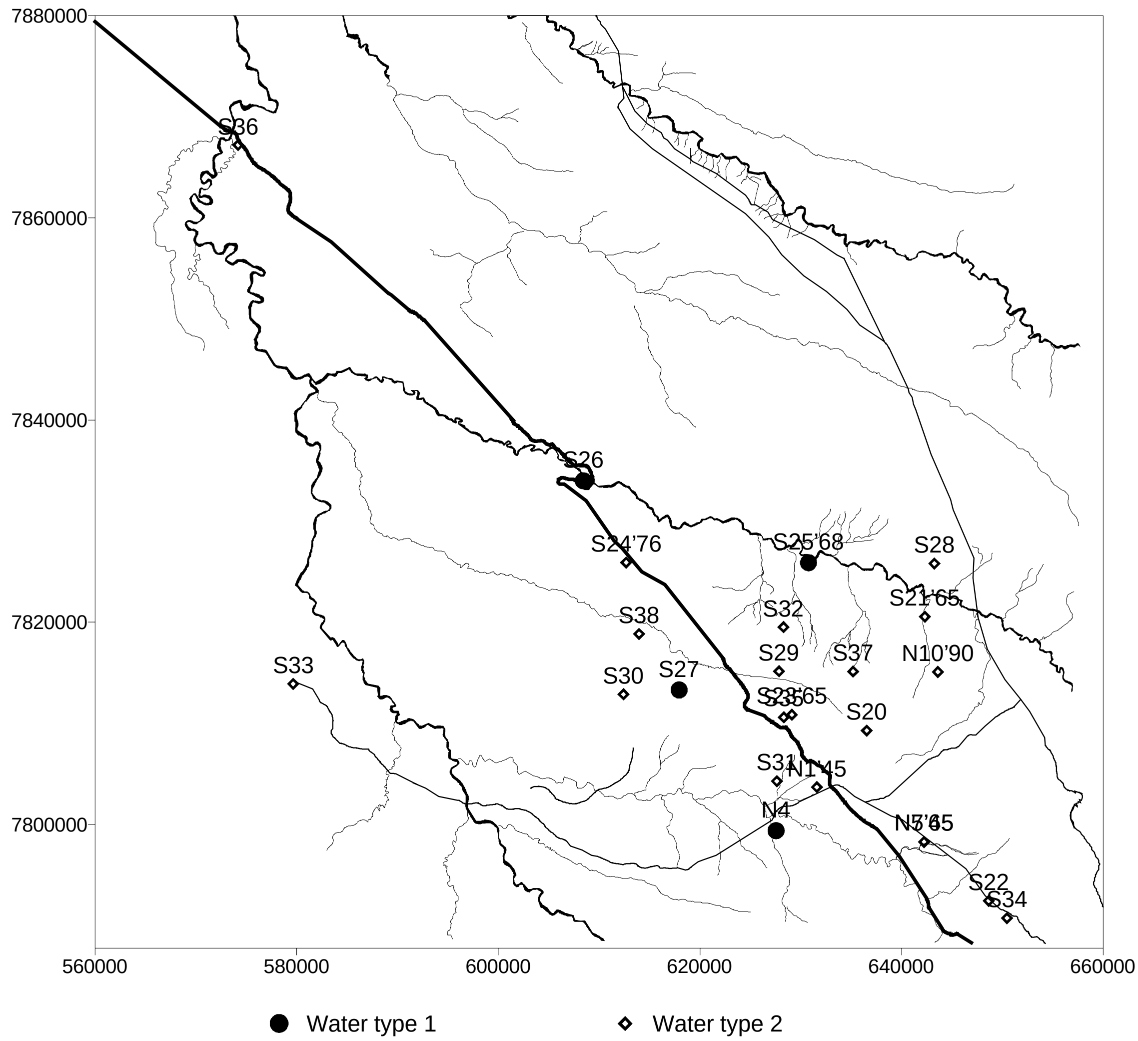

Figure 4. The spatial distribution of the two main water types in Karoo Sandstone

Borehole	pH	O_2	EC	Ca^{2+}	Mg^{2+}	Na^+	K^+	SiO_2	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^-	F^-	$_PCO_2$ (atm)	C-14 pMc	^{13}C	^{18}O	^2H	3H TU	36-Cl/L 10^7 Atmos	$^{36}Cl/^{35}Cl$ 10^{-15}
Type 1 Ca-HCO3 Groundwater																					
S20	7.02	4.3	346	28.3	11.4	12.8	0.7	35.3	206.2	2.1	0.2	2.8	0.5	2.0E-03							
N5	7.01	3.3	714	67.9	24.9	23.6	1.2	31.0	441.0	10.4	0.2	7.7	0.3	4.5E-03	86	-	-5.32	-38.2	<0.8		
N1	6.89	3.85	629	65.7	19.4	17.0	1.4	30.7	368.4	17.3	0.1	3.0	0.0	4.9E-03	37	-	-6.68	-45.5	0.9		
S21	6.91	2.4	836	84.6	22.1	22.4	1.6	26.6	463.6	8.3	2.7	22.4	0.0	6.2E-03	86	-13.0	-5.52	-39.2	<0.8	10.0	7.06
S22	6.9	2.3	866	90.9	22.3	24.8	1.9	25.2	363.6	11.2	8.9	44.4	0.0	4.7E-03	82	-10.7	-5.87	-39.2	<0.8		
S23	7.2	3.6	489	46.5	15.5	15.9	1.2	31.4	277.6	4.4	0.4	7.5	0.0	2.0E-03	74	-14.5	-6.19	-42.3	<0.8		
N10	6.86	1.5	660	72.2	18.2	18.8	2.1	25.4	405.7	4.7	0.0	1.7	0.1	4.6E-03							
N7	7.01	0.6	629	65.6	20.9	15.1	1.4	25.1	398.3	2.6	0.1	0.4	0.1	4.0E-03							
S28	6.81	3.0	643	73.1	19.3	8.9	3.3	15.1	395.3	9.0	1.1	7.6	0.0	6.3E-03							
S29	7.07	2.3	511	51.4	14.6	15.8	1.4	28.4	317.2	2.5	1.2	0.8	0.0	2.8E-03							
S30	6.71	1.7	789	80.9	24.2	17.8	2.4	31.1	419.7	20.1	2.1	34.4	0.0	8.5E-03							
S31	6.59	2.6	733	70.2	25.7	16.5	0.4	26.5	362.3	15.7	26.5	31.7	0.0	9.6E-03							
S32	6.88	3.3	648	55.7	14.1	32.5	3.4	19.9	371.5	10.2	1.6	12.2	0.0	5.1E-03							
S33	6.74	3.2	1042	98.9	32.0	33.0	1.5	28.7	534.4	21.6	7.3	42.4	0.0	10.0E-03	93	-11.4	-6.02	-42.3	<0.8		
S34	6.65	3.7	691	75.4	18.7	13.2	1.9	23.5	343.4	18.3	3.4	25.4	0.0	8.0E-03							
S35	7.19	6.4	649	59.6	16.3	18.6	1.3	29.0	223.3	25.8	7.7	71.9	0.0	1.5E-03							
S37	6.8	2.5	617	61.5	20.3	17.2	0.7	32.3	391.6	5.5	1.2	3.6	0.0	6.4E-03	94	-15.5	-6.38	-42.3	<0.8		
S38	6.96	2.1	716	76.3	21.7	19.2	1.5	28.6	462.4	2.1	1.2	0.8	0.0	5.2E-03							
Type 2 Na-HCO3 Groundwater																					
S25	9.1	2.2	465	1.0	0.1	87.3	1.0	6.2	263.5	11.4	1.3	1.4	0.1	2.2E-05	4.9	-11.2	-6.60	-43.7	<0.8	13.4	6.9
S26	9.11	0.2	833	0.5	0.1	154.9	0.7	6.6	457.5	30.2	15.5	0.0	1.9	3.7E-05	0.89	-12.0	-7.10	-47.5	<0.8	10.4	2.03
S27	9.4	1.4	814	0.8	0.0	140.9	0.8	9.9	316.0	24.0	63.4	0.8	4.0	1.4E-05	0.04	-10.8	-6.92	-46.8	<0.8	7.1	1.75
N4	9.38	0.7	1079	44.5	0.2	130.0	2.0	10.0	27.5	21.1	266.9	0.0	5.3	0.1E-05			7.08	-47.0	<0.8		

MANYAME Catchment Council: a review of the reform of the water sector in Zimbabwe

CJK LATHAM

Centre for Applied Social Studies, University of Zimbabwe, ZIMBABWE

ecoed@ecoweb.co.zw

1. INTRODUCTION

The Government of Zimbabwe embarked on a reform of the water sector in 1996. Informing this decision was a belief that the Water Act of 1976 (in turn a revision of the original Water Act of 1927) was inadequate in a number of areas.

Reform of Water - The Imperative

As far back as 1996 the Government of Zimbabwe indicated the principles that it hoped would be enshrined in a new Water Act (finally promulgated in 1999) in order for it to be an effective instrument for the reform of the management of the country's water resources. These were:

⇒ All surface and underground water will belong to the State
⇒ All Zimbabweans must have access to water for primary use
⇒ All water must be beneficially used
⇒ Water should be treated as an economic good
⇒ Water tariffs will need to take cognizance of those unable to pay the full price
⇒ Water rights need to be replaced by water permits, which will not be issued in perpetuity
⇒ Water management should involve all stakeholders at the lowest possible level and
⇒ The environment is to be considered as a consumer in its own right (Supplement to the Business Herald October 10th 1996).

There was almost universal consensus amongst water administrators, legislators and academics that the Water Act of 1976 was in need of reform or replacement. This perception was strengthened by world trends concerning the management of water and the increasing reality of tensions and conflict related to access to resources. As Kambudzi states, "In the aftermath of the conflicts experienced during the Cold War... the next basis of local, national, regional and international conflicts will be <u>resources</u>: fuels, minerals water etc. Water, especially agro-water and fresh water, offers the largest potential for local, intra-state and inter-state conflicts. Even wars between villages are likely to occur over how water resources should be developed, shared, used and managed." (Kambudzi A. M. 1997)

"At international meetings about resources we have frequently heard the statement that ...in the 1990s some countries or regions will have to stop their growth or go to war, or both, because of the shortage of water." (Meadows D. 1992:54)

" Awareness of the concern for the problems associated with the use of water resources have increased world-wide. Two major aspects of these problems involve the alarming rate at which water supplies are being depleted and the conflicts arising from competition in allocating the scarce water supply. In addition, a common problem among developing countries is the lack of guidelines for the development of water resources and for the distribution of water among competing users." (Cruz, CJ; in Berkes, et al 1989:219)

The African Development Bank (1994) predicted that many southern African countries including South Africa, Kenya, Malawi, Mozambique and Zimbabwe might be living beyond their present water potential.

Perhaps the most important issue to emerge from the debate by stakeholders over the last several years *was the need to move away from a rigid and centralized system of water allocation by government to one where users have greater control over water and its management.* Driving this process was a perception that greater equity in the access to and development of water resources was not only desirable but also necessary in the national interest. Coupled with this was the thrust towards greater democracy and local participation in the management of natural resources. (Nhira C 1993).

The Water Act of 1976

The 1976 act was premised on two principles. Water rights were issued in perpetuity and attached to a parcel of land. Water rights were issued in terms of a priority date - the older the right the greater the priority the right had over others for the appropriation of water**.** The priority date system (PDS) and the lack of real local participation in the allocation of access to water were to be major influences in the move towards a reform of the water sector.

River Boards

The act of 1976 encouraged the notion of River Boards. There was an understanding that the Ministry of Water Development was unable to monitor the use of water by right holders. Perhaps it was also believed that a degree of local involvement in the administration of water was desirable. River Boards could be formed on a voluntary basis. Their charter allowed them to raise levies on water rights in their areas of jurisdiction and to monitor the use of water by right holders. However, water rights were still issued by the Administrative Court sitting as the Water Court. River boards could be consulted on applications for water rights but had no power over the court's decisions. Rulings and adjudications were based on reports from The Ministry of Agriculture Extension Service (Agritex) and Water Development (MOWD). The judge sat with two assessors who were generally serving or retired officials of MOWD. This meant that river boards were little more than bodies set up to police the use of water. This in the main they did successfully unless conflict arose. If local informal arbitration was unsuccessful, contestants had to resort to the courts because boards had no authority to enforce arbitrations. More significantly, river boards, despite intimate local knowledge of their catchments had little real influence over the issue of water rights. River Boards operated exclusively in the LSCF areas. (Latham 1999)

Priority Date System

The 1976 act perpetuated the allocation of water rights using the principle of priority dates. The older the water right the greater priority it received in access to water. As nearly all rights related to commercial farms and the older communal land irrigation schemes, it prejudiced the development of new entrants to the use of water for commercial purposes - particularly for irrigation. (Manzungu 1996; 1999)

2. THE WATER ACT OF 1998 - THE NEW LEGAL FRAME WORK

The new act differs from the old in the following major areas.

The priority date system of water allocation is replaced by proportional allocation of water once an outline catchment plan has determined the volumes available.

Water permits replace water rights. Permits are issued for a specific period where as water rights were issued in perpetuity.

All water belongs to the State, including ground water.

Seven catchment councils, on the recommendations of their sub catchment councils issue permits. An elective process forms catchment councils and sub catchment councils by identified stakeholders.

A Zimbabwe National Water Authority, a parastatal body set up by separate statute, administers all water, replacing the Ministry of Water Development. The Minister of Water Development appoints the ZNWA board members. Four members of the board are recommended to the Minister by the seven catchments. The Ministry is downsized to a small body of professionals with a sapiental and advisory role within the water sector.

3. PRE-PROMULGATION: 1996 -1998

3.1 Mazowe and Mupfure:

Although enacted in 1998 the President did not sign the new act into law until 1999.

Before its enactment a donor sponsored body known as WRMS (Water Resources Management Strategy) was formed to formulate strategies and guide the process of reform. One of its main objectives was to maximize stakeholder involvement. The Mazowe Catchment was chosen as a pilot catchment in which dialogue with and participation by stakeholders and professionals could help in the evolution of the new legislation as a framework for a new approach to water management. Informing the process were the principles outlined in the introduction to this paper. The Mazowe initiative was sponsored by GTZ, a German Government development agency.

Alongside the Mazowe programme the Royal Netherlands Government sponsored a similar programme in the Mupfure basin, later to become part of the Sanyati Catchment. The new Water Act once promulgated was introduced in these two areas before being introduced in other catchments.

3.2 WRMS and Stakeholder Groups

WRMS, academics (CASS BASIS/CRSP Team) and stakeholder groups in these areas undertook considerable work. Recommendations and suggestions deriving from stakeholders as well as academics and professionals in the water sector seem to have driven the process of evolving instruments for the governance of water. Other catchment areas received little or no attention. Stakeholder groups, particularly commercial agriculture, began to show increasing signs of unease. This focused on the proposed levy system and the repeal of the priority date system based on water rights. Even in commercial agriculture, however, there was a convergence of opinion with others in the sector about certain fundamental issues. For example, a National Irrigation Liaison Committee was formed consisting largely of river board chairmen. At its meeting in February 1996 the pricing sub-committee reported that "all consumers of water should be levied to cover the proposed ZINWA costs: municipal water, agreement water, righted water, water in private dams, and borehole water. Primary rights should not be subject to this levy." (CFU NILC 1996 Minutes 202240 dated 1st February 1996.) The quantum of levy and the purposes to which it would be put were always an area of contestation with some members expressing deep concern at the viability of certain crops if the levy was too high. Others called for maximum decentralisation of collections and administration of water. Another frequently heard demand was for maximum transparency in the administration of levies so that those paying could be satisfied that their money was being put to good use. Much of this discussion took place in the confines of the stakeholder group. There was little liaison and interaction with the WRMS, Government or the donor agencies.

3.2.1 Commercial Agriculture

Commercial agriculture became increasingly concerned at the perceived threat to its interests. To this end it restructured the NILC into a Water Committee and created Regional Water Committees at provincial level. One such committee was formed for Mashonaland West (North) region that covered the Manyame Catchment. Its chairman wrote to the Minister (undated but from file order some time in 1997). Her concern was the then proposed development levy. "If a development levy is to be introduced it should be done so that the whole of the Zimbabwean community is involved, not only the users of water." Her argument was that everyone benefited from water development not just the users. And again: "The levy charged to the irrigators should only be for the policing, monitoring and management of the water resources."

In 1997 (notes for a meeting with the minister regarding the seventh draft of the new act) she noted for discussion that "so far as the water pricing policy was concerned some 90% of ZINWA funds would come from commercial agriculture, yet the Bill as it stood omitted any reference to stakeholder input in the pricing of water." Typically concern was also being expressed about the conversion of water rights to permits. One commentator stated: "Under this system (permits) the permit will be valid for a specific period and will be subject to revision. The permit can be canceled for no apparent reason. This will obviously lead to all forms of corruption as either those who loose their permit try to regain them by illegal means or a prospective user trying to gain this permit by bribery. He that pays the most gets the permit." (Anon Regional Committee Mashonaland West, February 1998) Another stakeholder asked: "What is going to happen to the user who has put infrastructural development in place and trained staff to operate these schemes when his permit is canceled and no more water is allocated to that property." (Ibid 1998).

By the end of 1998 a noticeable difference of opinion concerning the reform of water in the LSCF sector was apparent. Most Mazowe Valley farmers understood and argued for changes to the priority date system, the need for equity and the development of resources in areas previously disadvantaged. For example (Mr Walters, Mazowe) "spoke of the fractional allocation system that would guarantee absolute equity of access." (Meeting, September 1998; page 6). This was contrary to remarks made by members of the Manyame (Mashonaland West (North) committee at about this time who felt that the priority date system was the only way to manage water fairly. "The priority date is seen by some as preference or superiority but should rather be seen as rank or tenure. Every facet surrounding our lives revolves around priorities -whether we go to the bank, the bakery supermarket or passport office. We find we have to queue. Those who are first in line get served first and if the commodity has run out those that remain in the queue cannot be served. A country or an army cannot function without priorities or rank, neither can the monitoring of water." (Anon: Mashonaland West (north) Regional Committee: February 1998)

3.2.2 Pricing and levies

It is clear from the on-going interaction between WRMS/Government and the CFU that increasing frustration is expressed over the pricing mechanism and policies. CFU fight the prices at every turn, citing viability of crop production. Government and WRMS officials express sympathy but do not swerve from the determined course to introduce mechanisms that bring in revenue for development and create a demand management scenario. "Price manipulation is acknowledged to be a potent tool in controlling the distribution of water - and stakeholders are charged with the responsibility of managing the resource at local level, but, are specifically barred from using the pricing mechanism in their endeavors." (CFU executive officer’s report 18.3.98)

3.2.3.Stakeholder Involvement: Manyame Catchment

Another area of conflict was the perception of the lack of stakeholder involvement in the process. While this has some empirical justification it is also true that a number of workshops and meetings were held during the period 1998 1999, not least one at ART Farm on 19th January 1999 addressed by a number of speakers including farmer representatives. At this meeting there was a strong message from all speakers for the need for more stakeholder involvement in the debate. Perhaps the major constraint on stakeholder interaction was the perception that someone other than the stakeholders should ensure that such communication occurred. There was a perception amongst Manyame commercial farmers that a process similar to that in Mupfure and Mazowe would be embarked upon before the introduction of the new legislation. And amongst communal farmers, small-scale farmers the UIM users and representatives of rural district councils there was an almost complete lack of any meaningful consultation. This researcher made frequent visits to Guruve Rural District Council, (GRDC) Zvimba Rural District Council, (ZRDC) and to rural communities during this period. They all professed a complete ignorance of any water reform process. (Even in the Mazowe catchment, one chief interviewed in late 1999 stated that he had been to one meeting at Rushinga but this had left him with a less than clear notion of what was happening. His exact response to the question "Have you heard of a new Water Act?" was "What Water Act?") (Personal communication, Chief B 1999). Household surveys in one area of communal land in Guruve showed a 90% negative response to the same question. A later informal Rapid Appraisal in the same area showed a trend towards a perception that the new legislation would result in "development schemes being introduced in the form of dams and irrigations schemes and that these would be undertaken by the new "kanzuru ye mvura" - catchment council. (This was the first hint of a developing trend - an emerging perception by some councillors on the GRDC that the catchment council posed a threat to their positions.

4. FORMATION OF LOWER MANYAME SUB CATCHMENT COUNCIL AND MANYAME CATCHMENT COUNCIL

Almost as if to give substance to the concerns of some stakeholder (LSCF) and to the bewilderment of others, a meeting was called at Horseshoe Country Club, in Lower Manyame Sub catchment area for the 21st July, 1999. It is not clear from the records as to how much notice was given but oral reports state that it was "at short notice'. Stakeholder groups identified by officials from WRMS and the Ministry were advised to be present in order to vote for councilors.

4.1 Formation of Lower Manyame Sub Catchment Council:

The meeting convened at 10:30 am with the District Administrator in the chair. He apologized to the assembled audience for the fact the two provincial water engineers; the provincial governor and local Member of Parliament were late and assured those present that they would be coming. (This conveyed a message to the audience - or at least some it - about the importance attached to the meeting by these senior persons.) A relatively junior official (who was very nervous) gave a brief, inadequate summary of the water reform process, the ZNWA Act and the formation of sub-catchment councils. He was followed by a provincial water engineer who had now arrived, who then briefed those present on how they were to select members of the SCC. Each stakeholder group was to caucus and select five members of which two would be proposed for the council. Stakeholder groups identified by the officials were (in no particular order)

Large-scale commercial farmers
Large-scale (Indigenous) commercial farmers
Small-scale commercial farmers
Communal Farmers
Rural District Councils
Large-scale miners
Small-scale miners
Industry and commerce
Resettlement Farmers

Stakeholders reconvened in a plenary session. The District Administrator then announced that each stakeholder group would be allowed five members who would be asked to vote for office bearers for the council. However, first they were to identify two of their members as their choice for councillors. The Provincial Water Engineer Mashonaland West, Eng. Makokove then addressed the audience telling them he was to be the acting catchment manager. He stressed the importance of choosing wisely. Finally it was reported that sub catchment council would have two members on the catchment council and it was agreed that these should be the chairman and his vice-chairman. Voting for the office bearers followed. The Member of Parliament (Chindori-Chininga) closed the meeting by stressing the need for high calibre councillors, regardless of colour or ethnic origins.

Study of the list of people present at the meeting suggests that canvassing was poor. Commercial farmers were well represented simply because their superior communications network (radio) was employed to alert them of the pending meeting. Also as the stakeholders most vulnerable to the impact of the new legislation they had a direct and pressing need to be there. The numbers are revealing:

Large Scale Commercial Farmers	16
Indigenous large scale commercial farmers	2
Communal land farmers	4
Small scale commercial farmers	4
Resettlement farmers	1
Industry and commerce	2
Local Government (excluding officials)	2
Large scale miners	5
Small scale miners	1

4.2 Formation of the Manyame Catchment Council

A week after the formation of the Lower Manyame Sub Catchment Council, a meeting was convened to form the Manyame Catchment Council. Much the same format was adopted by the chairman - in this case the Provincial Administrator. The meeting was advised that the chairman and vice-chairman of each sub catchment council automatically formed the catchment council. Only they would be permitted to vote amongst themselves for their chairman and vice chairman. Other members present were asked to leave the room while the councillors voted. Three people were proposed: Chief Bepura (CA) and P Nicolle (LSCF) were seconded. A third councillor, Mr Mutero was proposed but received no seconder. Councillors voted and Bepura was elected by a majority of eight to five. Before the start of the meeting intense lobbying was observed. This was amongst members of the different farmer stakeholder groups. It became obvious when they voted that their intention was to ensure that they secured the chair and vice chairman's posts. (Mr Mutero, the only other councillor nominated represented local government interests.)[1]

5. TRENDS AND PRACTICES

5.1 Introductory Note

Certain trends and practices have been identified within the institutional activities of the Manyame Catchment Council. Within the catchment area specific observation of the Lower Manyame Sub Catchment Council supports the notion that these may be common to all sub catchments in the catchment. One should note, however, that two of the sub catchments were largely dysfunctional from the start, due to intense and often violent political activity within their areas. In the case of Angwa-Rukometchi SCC the battle over land in the Karoi and Tengwe LSCF areas, the intense and sometimes violent campaigns in the towns of Karoi and Kariba had a negative impact on SCC. Attendance at meetings was sparse. The chairman eventually left his farm and has since emigrated. Only within recent months has the SCC begun to function, largely because of interventions by the CC chairman. (Outreach meetings and capacity building meetings with councillors.) In the case of Musengezi SCC similar extreme political tensions caused the collapse of the council. The chairman was subjected to considerable intimidation and violence erupted on his farm on a number of occasions. In due course he resigned from the SCC "disgusted with the general collapse of law and order" (personal communication). His vice-chairman took over as acting chairman, himself only to fall victim to the prevailing violence in the area. He is still recovering from a savage assault that took place in the Mzarabani area. Mzarabani has been the arena of intense and violent confrontation between supporters of the ruling party and the official opposition party.[2] Musengezi SCC has not been able to function since inception of the CC. The other sub catchment councils have met regularly and made some slow progress.

5.2 Duties and responsibilities of councillors:

Because most councillors were voted onto their respective councils with little or no previous background of management of water nor of the intentions informing the reform process, there was an obvious and articulated need for orientation and training in their newly acquired roles. At its first meeting members of both the Lower Manyame Sub Catchment Council (LMSCC) and the CC expressed a need for training. The chairman (who is chairman of both the LMSCC and CC) endorsed this requirement. Although the CC has been functioning for nearly two years it is only now (June 2001) that training has commenced. Lack of direct control over its budget is possibly the main reason for the delay. For example, the LMSCC planned to hold a training session at Kanyemba. The donor organisation funding the CC refused to release funds for the workshop because they alleged that it was too expensive.[3] Another reason was a possible lack of capacity on the part of the CC to mobilize suitable facilitators. This in turn is an example of the problem of expecting professional engineers (catchment managers) to be skilled in human resource management and general administration. Lack of suitable training and orientation, not only of councillors but also of the new staff assigned to the CC, has contributed to the slow progress made in the Manyame catchment.

[1] This rough alliance of farmer stakeholders from all sectors of Agriculture in the face of UIM and other stakeholder interests has been a remarkable feature of the catchment council's operation from inception to date.

[2] It is ironic that the vice chairman Chief C was a leading figure in the invasion of farms in the Centenary area, while the chairman JJ H was a leading figure in the commercial farming community. JJ H and his family for at least three generations have also been prominent in the promotion of education in the region and were regarded with some suspicion by the Smith regime before they were targeted by racists elements in the current ruling party.

[3] The workshop was finally held at Mazowe and cost more than the budgeted figure for the workshop planned at Kanyemba.

5.3 Representation and participation:

An analysis of the minutes of the Catchment Council reveals a tendency for discussion to be dominated by LSCF members. Two reasons for this are offered.

The LSCF members (most of whom had served on the defunct river boards and were more familiar with the management of irrigation water) seem to have had more confidence than those councillors from stakeholder groups newly introduced to the subject.

Most of the issues raised at meetings were of direct concern to commercial agriculture - user permits and levies in particular.

However at LMSCC level the tendency has been for LSCF members to take little part in proceedings. Their attendance at meetings has been poor. Where as at CC meetings were often dominated by discussion of issues important to LSCF at LMSCC the trend has been for meetings to be dominated by the concerns of communal and small-scale agriculture. At LMSCC the need for the development of outline plans and for these to include potential development of water resources has been discussed at most meetings. It has driven the process of outreach meetings in the rural communities. It has also been the cause of some concern and suspicion within the rural district council. Other matters frequently discussed are how to enforce environmental protection measures; the formation of user boards and the incorporation of water point committees, in the previously marginalised communities. At both SCC and CC level matters relating to agriculture (irrigation and the development of water resources) have been major subjects debated. Councillors representing mining have attended only two meetings at LMSCC level. Due to the method of election/selection of councillors at CC level[4], mining as a water-using sector is not directly represented. There has in consequence been no discussion of mining related subjects at CC. Councillors from Commerce and Industry have also been absent from meetings, or when present, have been passive rather than active participants in debate. This may be because they have not perceived any direct relevance or threat to their interests, or because this sector is inadequately represented. The City of Harare falls largely within the catchment area. Chinhoyi falls wholly within the catchment. The only councillor representing Harare was an official (City engineer) who stopped coming to meetings within the first year of CC operation.[5] No urban industrialist or commercial interests are represented on the CC.

UIM[6] water has only been discussed by CC in so far as it is perceived as a possible threat to farmers' appropriations. For example, the construction of the Biri Dam in the Middle Manyame SCC has engendered discussion on the attempts by Harare City Council to increase its appropriation of water from the Manyame and Chivero reservoirs. At its meeting in March 2001, the chairman, assured the council that on the "issue of the above dams being allegedly handed over to Harare City by the Government, the issue had been discussed at a recent ZINWA Board meeting and a consensus was reached that no other authority has the mandate other than the Manyame CC" (to allocate water from these sources).

In short, at both CC and LMSCC meetings, UIM water has not featured as a topic at either the operational or at the planning levels, except in so far as it might be perceived as a challenge to rural agricultural water.

The LMSCC and CC both have one female councillor. They have not raised issues specific to women's rights to water. The concerns of women in the previously disadvantaged rural areas have received no consideration at any meetings. The female councillors contributed rather as stakeholders, representing the sectors from which they were chosen.

5.4 Institutional and Organisational concerns

5.4.1 User Boards:

The CC guided by its chairman has been careful to retain the old river boards more or less intact as institutions charged with the managing of water at a tier lower than SCC. In areas where river

[4] Chairman and vice-chairman of each scc form the cc
[5] The engineer councillor was requested by the chair to give details of how much water Harare appropriated from the Manyame. He refused to give any figures and after some heated exchanges failed to attend any further meetings. While there may be other reasons for his withdrawal councillors have drawn their own conclusions.
[6] Urban, Industrial and Mining water

boards did not exist under the 1976 Act, the CC has been active in outreach programmes. The primary objective is to canvas the new act and introduce communities to the new council and SCCs. A secondary objective is the setting up of user boards. One such new board has been set up in the Chapota area of Chief Chisunga, on the Lower Angwa.

5.4.2 Spacial Boundaries: user boards, catchment and sub catchments

A consequence of the strategy of devolution to user boards has been the expressed need by CC and SCCs for clear-cut geographical boundaries. User board areas also require defined boundaries. The communities involved define their boundaries along a set of criteria linked to functional institutional arrangements, not hydrological watershed boundaries. In the case of Chisunga community, these include:

- village allegiance to their traditional leaders
- district provincial boundaries in place for over a century traditional and spiritual boundaries that have been in place for at least five hundred years
- roads, tracks and foot paths linking the community and the community to the outside world
- rivers that isolate the community during the rainy season.

The SCC boundaries, based on watershed boundaries, split the community between the Lower Manyame and the Angwa-Rukometchi SCC. This has been debated at SCC and CC and consensus is for the Chisunga community user board to be put entirely within the Lower Manyame SCC. Resolutions to this effect will have to be passed at the two relevant SCC and then at CC to conclude the matter.

A similar situation exists in the Doma LSCF area. Traditionally the river board administered itself as part of the Lower Manyame, closely linked to the Msitwe River Board on the east bank of the river. They formed jointly the CH2 Hydrological area. For administrative convenience, the Doma River Board included in its jurisdiction tributaries flowing into the Angwa. Again the Angwa forms a formidable barrier and in consequence the Doma community looks to Chinhoyi rather than Karoi as its administrative, commercial and marketing centre. They see no value in splitting their user board between Lower Manyame and Angwa Rukometchi because of the watershed crest (which is ill defined and winds through the farms) divides their community. The boundary between the Musitwe and Mukwadzi User Boards on the east bank of the Manyame has similar spacial boundary problems. These issues are all positive processes and are good examples of the workings of community-based management of natural resources (CBMNR) -in this case water.

5.4.3 Jurisdictional Boundaries:

Associated with the need for geographical boundaries to be agreed and delineated, councillors have frequently expressed the need for their jurisdictional boundaries to be set. In other words they want to know what authority has been devolved to SCC and user board level. How the water point committees in the CA are brought into the user boards is also an often-debated subject. And how the CC and SCCs relate to and work with the RDCs has been of a question raised in debate on frequent occasions without being clearly resolved.

5.4.4 Overlapping jurisdictions: spacial and institutional

The overlapping jurisdictions (spacial and institutional) between CC, SCCs and RDCs is a recurring theme. Adding further complexity is the size of the area of the catchment council, which overlaps four administrative provinces and eight administrative districts. CC and SCCs have done no more than identify some of the problems created by this arrangement and indicated a need to network with relevant stakeholders and key figures to work out modalities to maximize the efficient operation of their institutions and minimize conflicts caused by poor communication, conflicting interests and jurisdictions. (E.g. planning and identification of development projects)

5.5 Permits: allocation and administration

5.5.1 The Water Act of 1998 differs from its predecessor in the allocation of appropriation rights. Under the new act permits for the use of water may be issued by the CC (section 50). Section 47 states that any person wishing to construct a dam holding more than 5 million cubic meters (5 megalitres) or to abstract more than 100 litres per second from a stream must obtain a permit. The use of water for primary purposes does not attract a permit. Permits can only be issued once a catchment outline plan has been completed by the CC.

There has been a lot of discussion at meetings concerning the issue of permits. This has focused on the need for a catchment outline plan to be prepared and for water users to be informed of their legal requirements. The act makes provision for water rights under the old act to be converted to permits once an outline plan has been prepared. The CC deemed it necessary to compile a database of existing water rights (held under the old act) in order to establish current usage. Minutes of meetings illustrate growing frustration with the officials tasked with this work. Eventually, first the Upper Manyame, then the Middle and finally the Lower Manyame SCCs engaged their own staff to undertake this work.

5.5.2 In order for permits to be issued, applicants are required to complete application forms. Applications will require a fee in order to be processed. Again this process has been frustrated by delays at Central Government level, over approval of the wording of the forms and the scale of fees to be adopted. Debate at meetings reflects a sense of urgency on the part of catchment managers to force the pace with CC in order to speed up the issue of permits and thus the collection of levies. CCs will depend on levies collected for the payment of catchment managers and staff and the administration of catchment affairs. The CC has been quick to ensure no erosion of its power and authority in this regard. The Catchment Manager has been checked from acting on processing of permit applications without prior council approval. A detectable friction has been observed between council and management. (See below)

5.5.3 Proportional allocation of water: privately constructed dams and boreholes

Lengthy debates have taken place over the proportional allocation of water stored in privately owned and constructed water works. LSCF councillors have expressed in turn anger, confusion and dismay that such works, though financed and paid for by them do not necessarily entitle them *per se* to the water stored in these works. Time and exposure to the principles of proportional allocation of water, equitable distribution and compensation for investment in infrastructure has to some extent reduced the sense of deprivation experienced by these councillors and the stakeholders they represent. The issue remains a sensitive one with CC acknowledging that much work by way of outreach meetings needs to be done. A similar recurring trend concerning permits for groundwater abstraction is detectable. At a public meeting held to explain the new legislation held in Chinhoyi during May 2000, a white LSCF farmer with large investment in storage works complained. He had "invested millions in ensuring adequate water for his wheat. I have a water right and can plan my farm operations to ensure my winter wheat is not jeopardized. Now you are telling me I have to share this water with people who have no investment in the dam. That’s crazy as well as unfair." A Black LSCF asked about his borehole: "Will I have to get a permit for this and possibly share this water with others? If so, I am going to blow it up. Why should I share it with anyone? I dug it and put the pump on at my own expense to give me water for my crops"

5.6 Levies:

The issue of levies to be paid for the use of water has been a major issue starting before the inception of the act (see above) and continuing up to the present. This is an issue that specifically concerns LSCF interests.Several arguments are presented by LSCF in their reluctance to pay the levy as presently envisaged.

River Boards administered their own affairs in the past. To do this they raised a modest levy (usually about $4.00 per megalitre of water righted). In return the water users received a service that included policing of water rights by staff to ensure no abuse of water took place. Secretarial services were provided and in some instances advisory extension services were also offered. Users now argue that they will receive less service and have to pay 10 times the levy, such levy going to ZNWA and not to the CC or SCC that serves them. They will in effect still have to levy themselves at user board level to provide services they deem necessary while paying a very high levy to ZNWA the benefits of which will not accrue to them in any meaningful way.

Levies imposed at the proposed rate will seriously affect the economic viability of some crops, notably wheat.

Issues of security of land tenure threaten levies and indeed the whole question of water usage over land being designated for re-settlement.

The issue of levies -- both as to quantum and method of disbursement -- is likely to remain a sensitive and potentially divisive issue. On the one hand is the real expectation of development funds being created from surplus levies to enhance irrigation potential in the historically marginalised areas. On the other the perception that the "goose that lays the golden eggs" is going to be so penalized that no eggs will be forthcoming.

5.7 The Catchment Manager

Section 28 of the Act defines the functions and powers of the catchment manager.

"For the day to day management and administration of the affairs of the catchment council, there shall be a catchment manager *who will be an employee of ZNWA*). *In the performance of his functions a catchment manager shall act on the advice of catchment council and shall be supervised by ZNWA."* (My emphasis).

Here in lies the rub. Catchment managers run the affairs of the catchment under the control of their employer only taking advice from their councils. The CM may even under certain circumstances issue permits - the prime function of CC and the main area of its devolved power. From inception this issue has been a constant cause of disagreement between catchment council and ZNWA. Not only does it place the CM in an invidious position; it seriously limits the power of the CC to administer its own affairs.

Examples of frustration taken from the minutes abound. In one case a user board has waited over a year for staff of the CM to visit their area with a view to doing a feasibility study into small dams and weirs. In another area similar frustration is recorded concerning a feasibility study involving a large dam that will affect users from the SCCF, The LSCF and the CA. The control and use of the vehicle donated to the CC by GTZ is another area of contestation. This whole paradigm is concerned with the issue of accountability. Should the CM be accountable downwards to stakeholders or upwards to ZNWA? The present arrangement suggests the latter, a position the CC and SCCs are not prepared to accept.

5.8 Water and Land:

The association of water and land -- specifically issues of tenure -- has begun to feature at CC and SCC as well as outreach meetings. Of particular topical significance is the issue of levies as they relate to water rights/permits to land that has been held by private title deed and is now subject to seizure by the State. In terms of the Act any such permits as attach to a parcel of land are transferred with the land when it changes ownership. What is not clear, however, is how the land so seized is going to be designated. Will it be regarded as CA, small-scale commercial or simply resettlement lands? What will become of the permits? Who will pay the levies if permits are retained and in whose name will they be issued? In the case of the Biri Dam[7] the effects of the Government's acquisition of sixty percent of the farms involved in the scheme could jeopardize the potential to irrigate 4000 hectares of communal land in the Zvimba CA and the Chitomborwizi and Zowa SCCF areas. This has been the subject of keen debate.

Farmers who are in the process of having their properties acquired are understandably reluctant to pay levies or even contemplate applying for permits. The counter argument is that regardless of whether a farmer is to be moved off his farm, if he is using water he must be levied for it.

6 SOME CONCLUDING OBSERVATIONS

6.1 A common pool resource:

Water is a common pool resource. The fact that it is impounded in reservoirs either by the State or by individuals, or by groups of people living in Common Property Regimes, may affect peoples' perceptions of who they think owns or controls the water. Water is also abstracted direct from

[7] Biri Dam, situated in Middle Manyame SCC area, is reservoir on the Biri River, a tributary of the Manyame, constructed by a group of LSCF in partnership with Government. The water impounded will be used by commercial agriculture. It will relieve the off-take from the Manyame itself, thus freeing enough water for irrigation in previously marginalised areas. This is an excellent example of the new act providing greater equity in the distribution of water.

rivers and streams and from ground water sources. In each case, the tenure system (over land) and the commonly held perceptions of the community, have a direct influence on how appropriations are regarded by the community and the individual. The centrality of water as a common pool resource for the sustainable pursuit of agriculture (quite apart from the primary use of water for the support of domestic existence) provides an imperative for appropriate institutions of governance. Water, being a fugitive resource, presents further problems of complexity. Within these contexts, appropriators of water grapple with the problems of best practice for the equitable distribution and control of appropriations.

6.2 Rules for successful management of water:

Research (both theoretical and empirical) as well as civil science seems to converge as to what succeeds and what does not, in the management of water as a CPR. In no particular order some of identifiable ingredients of success seem to be:

Small is best i.e the smaller the unit of management the greater the chance of success - "jurisdictional parsimony"[8]. "People will tackle and solve problems themselves, given the time and opportunity. Only when people see themselves as contributing to solutions do they achieve sustainable environmental protection systems. (Murungweni 2000 pers. Com.)
Defined spacial boundaries
Clear-cut rules of access and exclusion -jurisdictional boundaries
The ability of user communities not only to make but enforce rules
Shared perceptions or world-views
Minimum State interventions and interference
Downward accountability is as important as upward and lateral

6.3 Decentralisation and devolution: concerns with scale

The analysis of the reform process in the Manyame catchment indicates that while some of these ingredients are present there are some noticeable omissions. The issues that dominate the debate at the various institutional levels involved in the water sector show a common element. The central theme that threads through this dynamic is the issues of devolution and scale. At all levels there is an articulation of the need for stakeholder empowerment in the management of water, from the planning of development, to the control of access; the collection and management of funds (levies) and the engagement, control and accountability of staff. A clearly discernible frustration is evident, rooted in the conviction amongst councillors and stakeholders at all levels that their local knowledge of how to manage their affairs is given insufficient scope to be effective. This manifestation of a need for downward accountability and upward transferability of needs and local knowledge encapsulates the central paradigm surrounding the issue of decentralisation.

7. END NOTE

The long-term success of the process of water reform in the Manyame Catchment will depend on whether the State has the commitment to provide the enabling environment for local management of water resources to become a reality. To achieve this there will have to be the political commitment; the courage to amend where necessary the legal framework and to find the resources to build the capacity of local institutions to cope with the complexities of natural resource management.

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[8] See Murphree (2000) who argues that the smaller the management unit, and the "nearer" to the resource the more successful will be its management. He terms this jurisdictional parsimony.

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Linkages between Productivity and Equitable Allocation of Water

Hervé LÉVITE and Hilmy SALLY

International Water Management Institute (IWMI),
141 Cresswell Street, Private Bag X813, Silverton 0127, Pretoria, South Africa

h.levite@cgiar.org

ABSTRACT

The rapid development of water resources in the Olifants River Basin in South Africa, while stimulating economic growth, paid little attention to equity considerations among different users. Some 90% of the population of the basin was excluded from access to water when the present pattern of water allocations was developed. The recently enacted and very progressive water law aims at ensuring greater equity in access to water so that the benefits accruing from different water uses will be felt by a larger number of users. This paper examines the implications of water reallocations on water use and productivity at the basin level with a special focus on opportunities for revitalizing and expanding smallholder irrigation systems that are currently performing poorly and in many instances going out of production.

INTRODUCTION

South Africa has embarked on a courageous reform of its legislation in order to deliver water for all and redress past inequities in the sharing of this resource. Decentralization of decision-making is expected to replace the former top-down management of water in this water-scarce country. While major, economically influential water-users are likely to express their views and be listened to during the new allocation process, small-scale irrigators could experience a much harder time. The notions of productivity and equity, supposed to guide allocation decisions, are sometimes antagonistic in nature. The example of the Olifants river, where competition for water is particularly significant, is used to discuss some of the challenges and opportunities that arise in trying to reconcile these different considerations and trace a way forward.

WATER USE IN THE OLIFANTS RIVER BASIN

Abstractions from the rivers in the Olifants basin have grown dramatically during the last century. The Department of Water Affairs (DWAF) estimated that abstractions were a few million cubic meters at the beginning of the century, then around 350 million cubic meters in 1950, 500 million cubic meters in 1970, and about 1000 million cubic meters in 2000 (DWAF 1991). The average rate of water abstraction was therefore around 5 % per year since the fifties, which represents a doubling every 15 years. This development, shown in the step-wise profile of figure 1, was entirely supply-driven, accompanied by the construction of major dams.

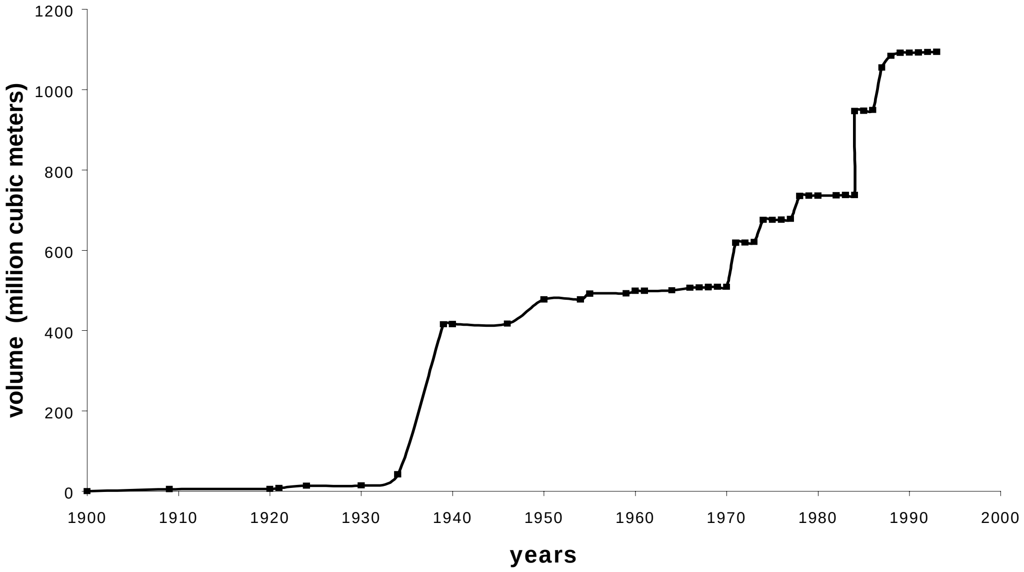

Figure 1: Development of water resources in the Olifants basin (*adapted from Midgley et al, 1994*)

Molden (2000) has suggested that the development of a river basin could be broken down into three phases: 1) a phase of development of water resources; 2) a period of utilization and, 3) a phase of reallocation, once the resources are fully utilized. However, it is of essential to know where we are on the depletion curve, in order to be able to make rational reallocation decisions (Murray-Rust 2001).

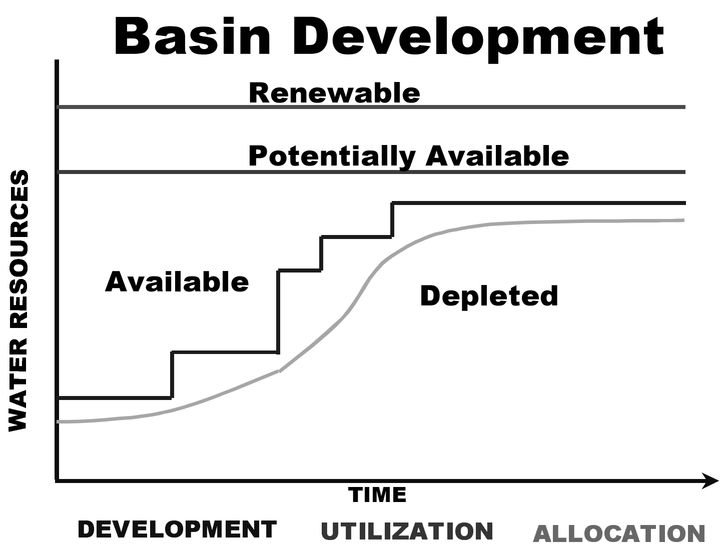

Figure 2: Phases of development of a basin (*after Molden, 2000*)

According to a recent technical assessment (BKS 2000), the water resources are expected to be fully utilized for large parts of the Olifants river basin by 2010. Indeed the projected demand for 2010 is 1375 million cubic meters. The study further states that environmental considerations as well as new water users will require decisions of reallocation between sectors, improvement of efficiency and possibly importation from other basins.

All types of water users are present in the 55 000 km^2 Olifants basin where 3.4 million people live.

- Agriculture is well developed, including livestock and an irrigated area of 107 000 ha.
- Afforestation represents 80 000 ha
- Domestic water demand from urban areas (middle sized cities)
- Power generation in the upper part of the basin; 55 % of the country's power is generated in thermal plants using coal from 50 mines.
- The mining sector is of paramount importance with 200 active mines (gold, platinum, tin, coal, etc.).

It is generally accepted that the water demand will increase during the next 10 years (see figure 3). However, it is worth emphasizing that half of the population is settled in former homelands and is particularly poor, having been forced into marginal areas, with few basic services (Wester et al, 2000).

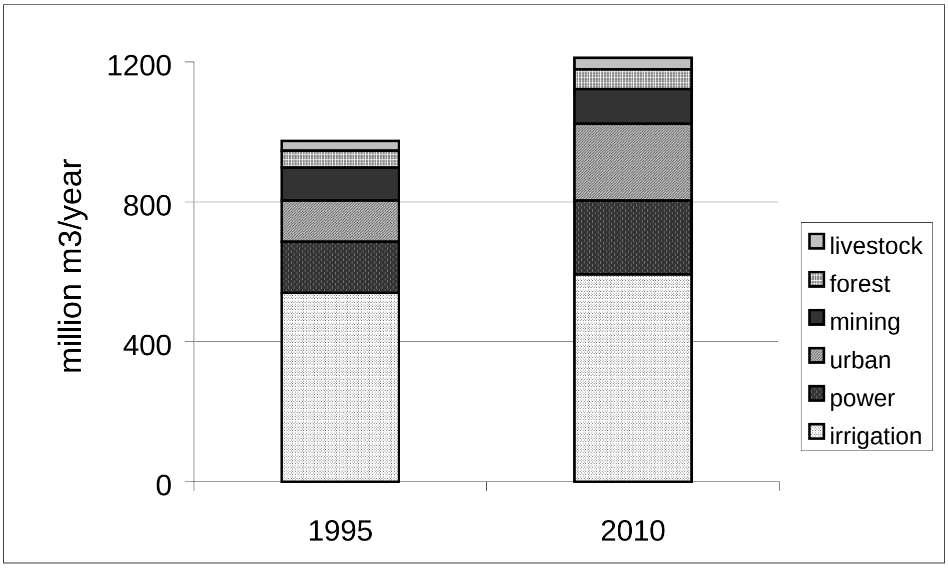

Figure 3: Water demand by sector (*source: BKS, 2000)*

From figure 3, it is immediately apparent that the main water user remains irrigation, which consumes nearly 50 % of the total.

White commercial farming dominates the sector with 95 % of the irrigated area, thanks to huge investments in the past (there are 30 major dams and a total of 2500 dams in the basin) and services provided by the state for decades. In the former homelands specific investments for agriculture were made for black people but one must highlight that it was essentially in order to develop subsistence agriculture or during the 60's to stop erosion (Thompson 2001).

Moreover degradation of the water quality in the rivers is increasing, due to direct and indirect pollutions from certain users (mines, industries), and difficulties of dilution. BKS gives an impressive list of water quality variables of concern: pH, Potassium, Sulphate, Fluoride, Magnesium, Sodium, Chloride, Fluoride, Aluminum, Iron, Manganese. A recent newspaper article entitled "A river dammed and destroyed" highlights the problems facing the Olifants (Mail and Guardian 2000).

The risk of heath problems is indeed high. The Olifants River has been ranked number 2 among the top 120 high potential health risk areas of South Africa (National Microbial Water Quality Monitoring Programme, August 2000). This is especially worrying given the fact that a large number of people in rural areas still take their drinking water from the rivers.

Insofar as quantity is concerned, low flows occurring during the dry season in the Olifants are sometimes so acute that it has even experienced periods of zero flow in the Kruger National Park. Although the calculation of ecological requirements is underway, it is likely that the minimum ecological requirements are already not being met in some parts of the rivers (Tharme 2001).

AN URGENT REFORM TO REALLOCATE WATER

Water sector reform was a priority in the agenda of the Mandela government (Turton 1999). As a matter of fact "the bulk of water available at the national level was consumed by the minority of the population", a phenomenon described by Turton as 'resource capture in hydropolitics'.

The unfairness of the situation in the water sector was so enormous that the constitution itself now guarantees access to water and a healthy environment for every citizen. Water resources, which were a private asset, become an indivisible national asset and riparian rights were abolished. The amount of water required to meet basic human needs and to maintain environmental sustainability, designated as the 'Reserve', is considered as a right.

In the National Water Act of 1998, three principles are underscored: equity, sustainability and efficient and beneficial use for the society, forming a kind of triangle of constraints for decision-making.

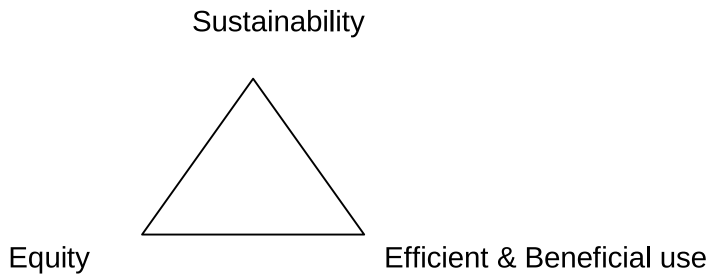

Figure 4: A triangle of constraints

The new legislation has also introduced the principle of management by catchment, which is now a notion accepted worldwide. The Catchment Management Agency (CMA) will be the apex body, governed by a Board, with a role of seeking agreement on water related matters among the various stakeholders. At the local level, Water User Associations (WUAs) are to be created. They are expected to help communities to find the financial and human resources needed to more effectively carry out water-related activities. WUAs are supposed to represent the people and ensure, for instance, that they have a voice in the allocation process.

There is a promise of decentralization. However, DWAF will provide the overall umbrella of water management decisions. Furthermore, until the effective creation of CMAs, DWAF will continue to play the major role in these foregoing (re)-allocations.

DWAF has deployed a lot of effort to organize the process of registration of all water users. After this stage, decisions regarding allocations (authorization or licenses, depending on the importance of water use) have to be made. It is almost certain that economic considerations will be of crucial importance and DWAF could be subject to pressures from very well organized economic lobbies (mines, industry, commercial farmers) or from the government itself, hard-pressed to show economic results.

HOW TO ALLOCATE?

The challenge now is how to translate these principles into practice; what mechanisms and tools are necessary?

Essentially, this boils down to trying to achieve a balance between allocations for equity and productive purposes while ensuring overall sustainable use of the water resource, as illustrated below.

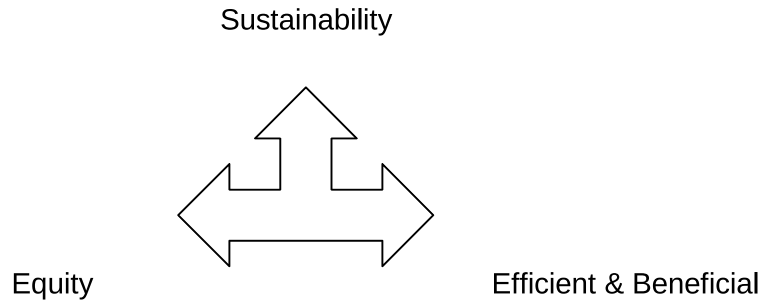

Figure 5: Balancing the needs of equity, efficiency and sustainability

Equity in allocation means that all users should have a fair access to the water needed for their activity. Sustainability can be understood to be the capacity of a system to endure. Efficient and beneficial use of water for the society must include optimal economic as well as social gain for the people.

In determining efficient and beneficial use, will considerations of economic efficiency dominate over social and equity principles? What kind of efficiency is beneficial? Once allocations are made will they be fixed? Or are there provisions that allow for adjustments and evolution over time (e.g. demographic change, changes in patterns of consumption and demand; indeed, the sustainability limits could also evolve, in relation to water quality objectives for instance)? Are the mechanisms envisaged for monitoring and enforcement of agreements adequate? Are the means of redress available in the event of non-respect of agreements (quantity and quality) accessible to less advantaged water users?

According to the law, a pricing strategy is expected to, gradually, play an important role with four objectives: social equity (redressing imbalances of the past); ecological sustainability; financial sustainability (obtaining full cost recovery) and economic efficiency (encouraging conservation of water and shifting from low to high value uses). (see Wallgren 2000).

Three different policies of water allocation are envisaged for the future (Wallgren 2000) namely direct control (by the State), water markets or public partnership (in a decentralized manner in the CMA). At this stage, decisions are still underway regarding the actual nature of the allocation approach.

THE SMALL SCALE IRRIGATION SECTOR

Coming back to the agricultural use of water by small holders, a key question related to the allocation process is whether this sector will be considered as contributing to efficient and beneficial use of water. The following sections will highlight what some of the related problems are likely to be.

1) Indeed this sector is already confronted with some real difficulties:

Under-utilization

As part of the current process of registration, DWAF has observed that, quite often, the existing water "rights" are not fully utilized. For instance, in the case of the Arabie Olifants Scheme (around

2 200 ha scattered in 14 schemes regrouping about 1600 farmers) only 30% to 50% of the initial allocation of water is used (de Lange 2000). There are a number of possible reasons for this situation of under-performance.

On one hand, State withdrawal was very sudden. On the other hand, the available management capacity of farmer organizations may not always be able to provide the same levels of technical expertise and support services as in the past; the infrastructure may also not be commensurate with small-scale farmer management. As a result, the operation and maintenance of the schemes would suffer, ultimately affecting production and the utilization of the available resources and infrastructure. In contrast, commercial farmers are generally more successful in upgrading and modernizing their irrigation systems even to deal with reduced availability of water. For them, making better use of water usually translates into higher returns, and thanks to the past and present state support, they are able to adapt their behavior very rapidly.

Low productivity

Given this scenario, it is possible that, in the minds of decision-makers, small-scale agriculture is not seen to be making beneficial use of water. A recent DWAF exercise in Kwazulu Natal (DWAF 2000) that computed water productivity for different uses and support services illustrates this (Table 1).

Table 1: Productivity of water for different uses

	Rands/m3
Paper/pulp industry	84
Mining	106
Citrus	2.78
Irrigated Sugar small growers	0.65

Inability to pay for water

The principle of a water charge, expected to be paid by farmers as well as other users, in order to finance the functioning of the CMA may be difficult to apply to the small-scale sector for a while.

Difficult mobilization of farmers as WUAs

The farmers of the small-scale irrigated schemes, which were often constructed by the government, are struggling to get organized (Wester et al.). They run the risk of being marginalized during the process of registration or during discussions within the new CMA structures.

<u>2) Numerous other considerations are imperative, but often neglected</u>

a) **All the externalities** must be taken into consideration (pollution, health impacts especially where people drink polluted water). Furthermore, environmental impacts have to be addressed in the long term. For example the impact of mining activities on the groundwater is often neglected. Jansen (2000) has shown that their impact on the catchment could be more severe after closure than during mining, extending over periods from tens to hundreds of years.

b) **Social aspects** like food security, malnutrition reduction, and job creation are crucial. Social impact questions such as ‘do the people of the basin really receive benefits?’ must be put on the table. **Historical considerations** are unavoidable since it is necessary to redress past inequities.

c) A principle, now widely accepted by IWMI and others, is to work in a **basin perspective** when we talk about water productivity. For instance water can be ill utilized at the farm level but re-utilized by other users downstream. Hence, the global water productivity can be quite good whereas local productivity is weak.

Similarly the spatial arrangements of water users in the basin are also crucial. For instance heavily polluting point sources of pollution will have greater overall impacts on water quality if they are located in the upper reaches rather than towards the tail of a basin (Murray Rust 2001)

Indubitably, new sets of considerations have to be put on the table (figure 6) in order to achieve a balanced choice during the process of allocation.

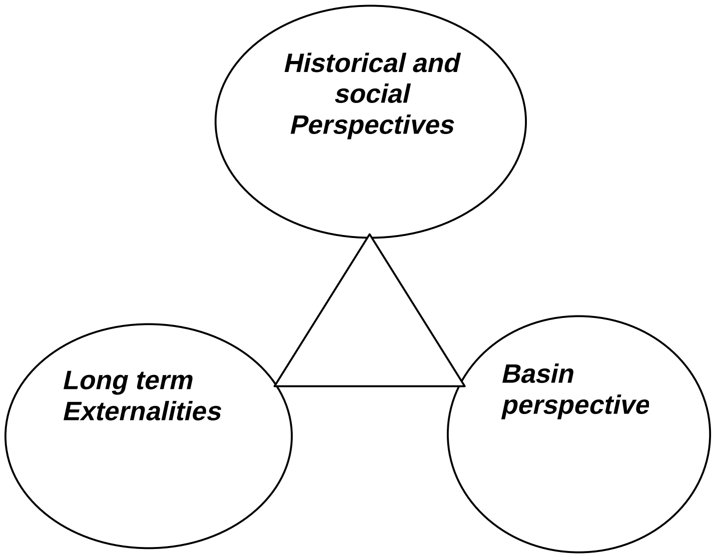

Figure 6: Supplementary forces expected to influence the triangle of constraints

CMA CREATION PROCESS IN THE OLIFANTS BASIN

The creation of the CMA in the Olifants basin is underway, with special attention from DWAF as it is one of the pilot agencies in the country. DWAF envisages a period of 5 to 7 years for that process. Whatever be the time period, what is imperative is that efforts to promote a real public involvement must not be jeopardized. As already stated, the CMA must be seen as a means of simultaneously meeting the objectives of equity and productivity of water at the basin level.

The main water users such as the mining and industrial sectors, water suppliers for the cities and commercial farmers are well organized and are ready to be registered. On the other hand the rural poor have difficulties to mobilize themselves. A study carried out by IWMI in the Steelport sub-basin of the Olifants (Stimie et al.) showed that rural communities are unaware of the CMA process, despite efforts made by DWAF to commission consultants for that task.

IWMI was commissioned in 2000 by DWAF to follow-up on the consultation process of the CMA. It was found, in short, that public participation requires more efforts than just forums organized by consultants, and that the latter as well as some DWAF officials see the CMA as a technical process, although it should be considered as a political one (Wester et al).

In theory, the “emerging farmers sector” in the Olifants basin is expected to grow (BKS 2000), thanks to different political initiatives (NDA 2001). But in practice, direct negotiations are already underway between the mines and farmers (with the assistance of the Northern Province Department of Agriculture and Environment) for the purchase of temporary irrigation water allocation for mining use. But in these discussions the small-scale farming community (representing around 1600 farmers) does not play a really authentic role (Kamara, 2001) and there is a risk that the pressure of economically active groups will determine the future orientation of principles and practices.

CONCLUSION

This paper attempted to highlight a foreseeable gap between a generous theory and a difficult practice in applying the principles of the progressive South African water law. While economics will undoubtedly play a major role in the allocation of water rights, one also needs to take cognizance of the notion of equity in the sharing of water at every stage. Indeed, equity must guarantee social and economical sustainability as poor people are afforded the opportunity to take off and improve their livelihoods thanks to a new access to water.

There is a need to further investigate the links between access to water and socio-economic benefits (for the society) of small-scale water resource development. Especially if there is a political commitment to really support this sector, one should do so with an open mindset and a long-term vision.

The results of research initiated by IWMI and its partners on valuing water in all its aspects, taking into consideration the different uses and users of water in a basin, should provide a basis for making scientifically sound and socially just decisions in regard to water allocation and water use.

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Domestic water supply, competition for water resources and IWRM in Tanzania: a review and discussion paper

Faustin P. MAGANGA[1], John A. BUTTERWORTH[2], and Patrick MORIARTY[3]

[1]Institute of Resource Assessment (IRA), University of Dar es Salaam, P.O. Box 35097, Tanzania
[2]Natural Resources Institute (NRI), Kent, UK
[3]IRC International Water and Sanitation Center, Delft, Netherlands

[1] efh@udsm.ac.tz

ABSTRACT

This paper reviews the historical development of domestic water supplies in Tanzania, the consequences of major policy shifts during the last seven decades, and some of the reasons for the failure of water supply systems. It considers the extent to which water resource issues are constraints in meeting the water supply needs of rural and urban populations, and the relevance of integrated water resources management to the WSS sector. Drawing upon case-study material from 2 major river basins, the Pangani and Rufiji, it reviews some of the practical steps being taken to implement IWRM principles in Tanzania.

Keywords: *domestic water supply; water resources; conflict; integrated water resources management; Tanzania*

1 INTRODUCTION

Tanzania's main water users are domestic consumers, industry, irrigated agriculture, fisheries and hydro-power generation. With a large and rapidly increasing population of 36 million[1], 80% live in rural areas, there are many and often conflicting pressures on the nations water resources (URT, 1995a). Although there is a theoretical priority in water resource allocation and development for domestic supply, in reality considerably greater resources are put into irrigation (for food security) and hydropower (for energy security) schemes.

- It is estimated that not only do less than 50% of the whole population currently have access to clean and potable water, but that over the past three decades per capita water availability has actually diminished in urban areas (while improving in rural areas) (White, 1972; IIED, 2001).
- Agricultural policy is to promote self-sufficiency and security in food and irrigated agriculture covers about 150,000 hectares, 80% of which are under traditional irrigation schemes.
- About 90% of electricity is generated by hydropower, mainly in the Pangani and Rufiji river basins.

Unfortunately, fragmented planning and management, a lack of integrated approaches and conflicting sectoral policies have contributed to increasing conflicts over water use (URT, 1995a). Conflicts[2] and inefficiencies make it imperative that available water resources are managed in a comprehensive manner, which takes into consideration the multiple users of water resources, land use impacts, pollution control, environment and public health issues. In line with international trends, this is the background against which Integrated Water Resources Management (IWRM) has come to the fore in Tanzania, as noted by a number of studies (e.g. URT 1995a & b).

IWRM promotes integration across sectors, applications, groups in society and time and is based

[1] *Demographic Data and Estimates for the Countries and Regions of the World,* Population Reference Bureau, World Population Data Sheet, 2001.
[2] Dylan Hendrickson (1997) defines resource conflicts as "a relationship between two parties who have, or think they have, incompatible interests in the use of natural resources".

upon the Dublin principles agreed in 1992. These recognise the finite and vulnerable nature of water resources, the need for more participatory approaches to development and management, and the economic value of water (Butterworth and Soussan, 2001; Visscher *et al.*, 1999). But what is the relevance of IWRM to the water supply and sanitation (WSS) sector?

It must be realised that there are arguments against the WSS sector getting more involved in water resources management. These include that:

- in many countries, although with notable exceptions where resources are severely stressed (such as groundwater in parts of India), the major constraints to developing rural water supplies continue to be a lack of appropriate investment and poor operation and maintenance of systems, rather than water resource constraints.
- IWRM is increasingly seen as being too complicated: as requiring that a whole list of individually challenging tasks are all completed before anything can be done. IWRM is seen as too long-term incapable of addressing real, current needs, whilst governments and water managers are faced with a whole host of immediate and tangible problems (such as domestic water supply and sanitation) for which practical solutions need to be found (Butterworth and Soussan, 2001).
- IWRM is viewed by some as the domain of basin managers (responsible for areas of thousands of square kilometres) who occupy themselves with managing surface water resources for irrigation (though the same water provides the main domestic supply for many urban centres), hydro-power, and the environment. While in many semi-arid areas (particularly in Africa) it is groundwater that is seen as the main resource for rural water supply (Foster *et al.*, 2000).

However, there are strong counter-arguments for closer involvement of the WSS sector in IWRM initiatives. These include:

- increasing awareness of competition for limited resources impacting upon domestic water supplies. India is perhaps the most severe example, where in many states falling groundwater levels due to over-abstraction for irrigation have led to the failure of traditional drinking water sources, and rural water supply agencies are unable to protect water resources.
- increasing pollution threats to water supplies, and,
- realisation that in practice the supremacy given to domestic water supplies in policy may amount to little when stakeholders are poorly represented in decision-making fora, such as river basin authorities or catchment management agencies.

This paper considers the role of WSS in IWRM in Tanzania, and aims to develop and explore these arguments. It is based on a review of relevant literature, as well as interviews carried out with regional and national actors (WHIRL, 2001). It also draws upon case-study material from 2 major river basins, the Pangani and Rufiji, where water resources management structures are being developed.

2 THE STUDY AREA

Tanzania has defined nine river basins for water resources administration (see Map.1) These basins include relatively small ones like the Ruvu/Wami, which flows into the Indian Ocean north of Dar es Salaam, supplying water for domestic and industrial uses; to large ones like the Rufiji basin, which covers eighteen percent of mainland Tanzania. Importantly, most of the existing hydropower plants are located in the lower part of river basins, while significant consumptive uses, mostly smallholder and large-scale irrigation, are located upstream. Thus, there is considerable potential for flow requirements for power generation to conflict with upstream water uses, particularly in the Pangani and Rufiji basins. With rising water demands for irrigation, and urban and rural water supply, the potential for water use conflicts is increasing and is recognised as such.

2.1 The Pangani river basin

The Pangani river basin has a total area of 42,200 km^2 (including 2,320 km^2 in Kenya). The basin carries waters from Mt. Kilimanjaro and the Northern Highlands into the Indian Ocean. It contains a big man-made lake called Nyumba ya Mungu, constructed for hydro-power generation. Since the 1930's power production in Tanzania had depended on the Pangani basin. At the moment there are 5 power stations in the basin, including Kikuletwa (not in operation), Nyumba ya Mungu (8 MW), Hale (21 MW), Old Pangani (15 MW) and New Pangani (66 MW). The basin is also within the Northern tourist area, which is one of the most visited areas in Tanzania, and contains the Arusha and Moshi industrial municipalities. A sizable area is also under traditional livestock keeping, which is also an important component in the overall water management in the basin.

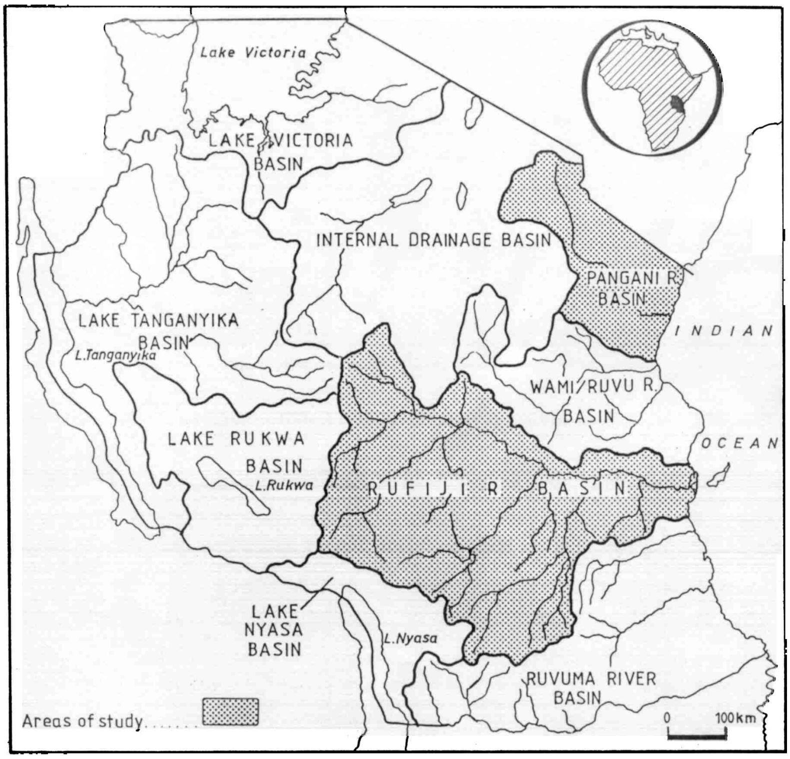

Figure 1. Map of Tanzania and the focus river basins, the Pangani and Rufiji.

According to a number of recent studies (e.g. Burra, (forthcoming) and World Bank (1997), water scarcity in the Pangani basin has resulted in a severe deficit in water available for multiple uses. As a consequence, sectoral water demands are not being met, water levels in storage reservoirs are low, and competition for water between farmers and hydro-power generators and between groups of farmers has intensified.

2.2 The Rufiji river basin

The Rufiji basin covers an area of about 177,420 km^2, and drains the Southern Highlands into the Indian Ocean. Various water uses co-exist in the basin, including domestic and livestock water supply; irrigation (mainly in the Great Ruaha and Kilombero valleys); hydro-power generation; fishing and wildlife water supply; and transport. The basin comprises four major rivers: The Great Ruaha, Kilombero, Luwengu and Rufiji.

Several studies have highlighted water resource problems facing the Rufiji basin (e.g. Baur *et al* 2000; World Bank, 1997; and URT 1995c). Within the basin, water scarcity is acute in the Great Ruaha basin, and this has resulted in very low water levels at Mtera Reservoir, the main regulatory structure on the Rufiji River. Since 1988, when the Mtera Dam was commissioned, water levels have been declining and have not recovered. Low water levels have had negative impacts on hydro-power generation, resulting in load shedding and rationing of electricity nationwide. According to URT (1995c), a number of factors caused low water levels at Mtera, including drought, increased upstream abstractions for irrigation, and poor operation of the Mtera reservoir.

3 HISTORICAL PATTERN OF WATER DEVELOPMENT IN TANZANIA

Although water resource issues are of increasing and long-term importance for water supply, until now the major challenges to the improvement of WSS in Tanzania have been ensuring adequate investment in appropriate infrastructure and ensuring operation and maintenance of systems.

Since colonial times Tanzania has taken several steps aimed at improving water supply and sanitation. This section highlights a number of these, starting with the pre-independence *cost-sharing* approach, the *free water* era and the present return to cost-sharing. Recent major events include the declaration of the 20 -Years Rural Water Supply Programme (1971-1991), the 1995 Water and Sanitation Sector Review, and the 1995 World Bank-inspired Rapid Water Resources Assessment.

3.1 Cost-sharing during the colonial period

Systematic water supply development in Tanzania began around 1930 when the colonial government started to use public funds for the development of water supplies to areas it considered to be of prime interest: townships, mission stations, large estates and trading centres. After construction these water supply schemes were managed on a self-supporting basis and all users were required to pay for the water they used. Active government involvement in the construction of rural water supply started in the 1950s, when local authorities were required to contribute 25% of the capital cost for water development projects, before the government would release the remaining 75%.

Earlier on, in 1945 the Department of Water Development was formed. Later, this department assumed irrigation development activities and became the Water Development and Irrigation Division (W.D.& I.D.). In its operations the W.D. & I.D. was concerned with three types of water supplies. The first was development of domestic water supplies for outstations and minor settlements whose construction was financed with central government funds. These supplies were owned by the central government and all users were required to pay a water rate that was calculated to recover capital, operation and maintenance costs. The second type of supply was constructed for Native Authorities (later known as Rural Local Authorities) to meet rural domestic and livestock needs. The Rural Local Authorities were required to pay a portion of the capital costs but operation and maintenance costs were solely the responsibility of the Local Authorities. People who collected water at the domestic point (kiosk) paid for water at a rate that was fixed by the respective Local Authority. The third type was known as prepayment water supplies. These supplies were constructed by W.D. & I.D. only after the client had prepaid the full capital costs of the water supplies. The client in this case could have been another government department, local authority, mission or even private estates (Warner, 1970).

Some local governments were able to collect enough money to pay for new water supplies and to operate and maintain the existing water supply installations within their jurisdictions while others could not. In particular, under the programme of cost sharing between the central government and Local Authorities, poor local governments could not make much progress in the development of rural water supplies.

3.2 The "free water" era

As noted by Mujwahuzi and Maganga (1998), the First Five-Year Plan for Economic and Social Development and the Arusha Declaration had a significant impact on the management of the rural water supply sector. For example, in 1965 the central government assumed all capital costs of water schemes development. From this date local authorities were left with the responsibility of meeting operational costs, while W.D.& I.D. retained the responsibility for repairs and maintenance provided the Local Authorities made an annual deposit of one percent of the total capital costs of all projects in their areas of jurisdiction (Warner, 1970). Towards the end of 1969 the central government decided to meet the costs of operation and maintenance of all rural water supply projects. This step made the central government responsible for both capital and recurrent costs of all rural water supplies. From this time water became a free good for a rural dweller. In urban centres, on the other hand, consumers who obtained water from metered public kiosks or those with house connections continued to pay for water. It was later decided that consumers who obtain water from public kiosks should also not pay for water. Consequently, people who continued paying for water in the urban areas were those who had either house connection or a water connection in the yard (Warner, 1970).

Subsequently, a new Ministry of Water Development and Power was formed and charged with the responsibility of planning and developing water resources in the country. It was made responsible for urban and rural water supply development as well as energy development throughout the country. It was also at this time (1971) that the ruling Party, The Tanganyika African National Union (TANU) made a major policy decision committing the Government to an objective of providing water in all rural areas so that every rural inhabitant could have easy access to a source of adequate and potable water by 1991. In 1980 the government adopted the UN goals for the Water Decade, and mobilised external assistance to prepare regional water master plans and facilitate rapid construction of water supply schemes. Foreign donors responded favourably, and 12 of the country's 20 regions were assigned to various donors. Despite efforts by government and donors, the target of providing every rural dweller with adequate potable water within easy reach was not achieved by 1991. Little attention was given to the ownership of the systems, and local communities looked at the installations as the responsibility of the government.

Thus, the "free water for all" approach did not meet the intended targets. As noted in the World Bank *Water Sector Study* (1997), in many areas the rate of systems failures exceeded the rate of new construction, yielding lower coverage in the face of population increase despite the high capital cost of the investments. Over 90% of piped schemes ceased operating, mainly due to an inability to provide the required fuel for pumping and to keep the motors and pumps in operating condition. Also, most of the hand-pumps on shallow wells stopped operating for lack of timely maintenance of repair. It was estimated that the installed capacity of constructed schemes could serve only 48% of rural people (World Bank, 1997). Regarding sanitation, the situation was also gloomy. According to World Bank figures (World Bank, 1997), around 68% of rural dwellers obtain their water from traditional sources, which are contaminated and pose health risks, as evidenced by incidence of water borne diseases, such as diarrhoea and cholera. Between 1986 and 1992 38,600 people throughout the country contracted cholera, out of which 4,364 died.

3.3 Return to cost sharing

In 1986 a conference was organized to review the experiences of implementing the rural water supply programme; to identify and address the problems encountered during the preceding 20 years; and to provide a framework for the sustainable development of water resources to provide an adequate water supply in the country (URT, 1996). The conference started the process of formulating a New Water Policy, which was approved by Parliament in 1991 (URT, 1991). The policy put an end to the "free water era" by introducing the principles of cost sharing in rural areas and full cost recovery in urban areas. Among its features were that:

- In rural areas, village governments were given the responsibility of running their small water supply systems, while the management of larger systems remained the responsibility of regional and in some cases national authorities
- A limited role was assigned to the private sector, stipulating that it might be involved in the provision of water supply services in areas where the Government was not able to do so.

The discussion on the previous section has highlighted the problems of a supply-driven approach to WSS. These problems can be summarized into three general issues – insufficient coverage, high cost and poor utilization (Kleemeier, 1995). The supply-driven approach was based of three major premises as to how donors and governments should supply water: (a) *Lowering the costs of implementation*, in order to spread coverage to as many people as possible, choosing the minimum level of service; (b) *Capacity building*: for government agencies to appraise, implement and manage water schemes and (c) *Subsidies*.

In contrast, the approach being promoted by the World Bank and other donors these days is a demand-driven approach, that is based on willingness to pay, and private sector involvement. A number of writers (e.g. Kleemeier, 1995) have expressed reservations about adopting these principles wholesale, because the demand-driven approach tends to be biased towards urban dwellers; also because of the poor capacity of the private sector.

4 WATER RESOURCES ISSUES AND WATER SUPPLY

Although in general water resources issues are not the most pressing problems faced by the WSS sector, WHIRL (2001) identified a range of water resources issues that are increasingly impacting on water supplies. These include:

- *conflicts over water resources*, for example, around the mixed use of irrigation systems. The traditional furrow systems are important sources for domestic supply and animals, as well as for irrigation. While the amounts used for livestock and domestic use are small, this use has important implications for irrigation efficiency because the furrows must be kept flowing to meet a regular demand. Interestingly, professionals working at the 'basin' level in 'resource' management frequently reported no conflict between domestic and other uses (typically concentrating on that between irrigation and hydropower), while those looking at management at the 'local' level (i.e. within irrigation scheme command areas or involved in domestic supply) reported considerable competition and potential for conflict.
- *pollution risks*, for example, the water supply for Dar es Salaam (from the Morogoro mountains) is affected by siltation and chemical pollution associated with commercial agriculture (e.g. sisal processing) in the headwaters. In addition, there is a growing problem of contamination from mercury used in artisanal gold mining.
- *sanitation and development of groundwater in peri-urban and urban areas*. Currently most drinking water is from surface sources, but there is increasing use of groundwater in peri-urban and urban areas. In Dar es Salaam the lack of an efficient distribution network is leading to widespread private development of groundwater, with people resorting to deep and shallow wells, and in some cases selling the water form their wells. The rapid rise in the use of shallow wells is leading to an increased risk of groundwater contamination from pit latrines.

5 IWRM IN TANZANIA AND THE ROLE OF THE WSS SECTOR

In previous years, Tanzania's development plans, including the rural water supply programmes, emphasised supply issues in WSS and did not consider water resources management aspects as an integral component. However, as discussed above, water resources management is increasingly becoming an important issue, especially considering the fact that major water users like irrigated agriculture and hydropower generation continue to implement parallel development programmes independent of each other.

In 1995 the World Bank and Danida funded a Rapid Water Resources Assessment (URT, 1995a), as part of a comprehensive Water and Sanitation Sector Review. The assessment highlighted the increasing competition for water resources in the Rufiji and Pangani basins, noting the growing demand for water for irrigation and domestic use. In addition, the assessment noted that there was considerable conflict between upstream irrigators and downstream hydro-power generation. This section considers the problems faced in these two river basins, and initiatives underway to address them.

5.1 IWRM in the Pangani Basin

Within the Pangani basin there are a number of water use-related conflicts. There is a potential pollution problem due to the increase of population and development activities, coupled with decrease of river flows. Sewerage treatment facilities in Arusha and Moshi municipalities are not effective, resulting in pollution of some of the rivers draining into the basin. Deforestation and land degradation resulting from agricultural activities and uncontrolled livestock numbers have resulted in erosion and sedimentation in the catchment. Fishery activities are important in both Nyumba ya Mungu and Pangani river. However, uncontrolled practices have undermined the fishing industry.

Another activity taking place in the basin is irrigation. However, the irrigation efficiency in all local furrows is very low, as the furrows are not properly maintained.

Under the provisions of the Water Utilisation (Control and Regulation) Act No. 42 of 1974, the Pangani Basin Water Office and the Pangani Basin Water Board were established in 1991in order to manage properly the utilization of water resources by different users in the basin, i.e. to allocate water rights; legalise, grant, modify and control water abstractions; protect the existing water rights; monitor the quality of the water and to take to court defaulters of the Act. So far the Board has taken the following key decisions:

- To stop issuing further water rights until the water situation has improved.
- To start a programme of creating awareness, monitoring systems and creating database for water resources.
- To introduce water user fees.
- To institute enforce bye-laws for source protection and other environmental issues.
- To develop a framework to managing the water resource at appropriate local level, by forming water users associations.
- To rehabilitate/construct 300 control gates.

A number of studies have indicated problems related to water scarcity in Pangani basin (e.g. World Bank, 1997, Burra, forthcoming). Upstream of Nyumba ya Mungu Dam, competition for water for irrigation has intensified, and it will worsen as populations and their water demands grow. The 2300 ha Lower Moshi Irrigation Scheme triggered rapid expansion of rice cultivation, and over 3000 additional hectares were put under cultivation, with the water being abstracted without water rights. As noted in World Bank (1997): “Increased upstream abstractions …have resulted in acute water shortages in the Weru Weru River, and this has constrained further development of the Lower Moshi Irrigation Scheme in spite of existing water rights. Efforts to address the water rights issue have resulted in violent physical and verbal confrontation”.

It is worth noting, in conclusion, that WSS needs have not been a major consideration in the Pangani basin.

5.2 IWRM in the Rufiji basin

Within the Rufiji basin, the greatest water use occurs in the Great Ruaha sub-basin, and already water shortages and water use conflicts are being experienced. Competition is mainly between downstream hydropower generation and upstream irrigation, due mainly to the design of hydropower schemes that did not take increasing irrigation demand into account. The situation is further aggravated by wastage of water as nearly all abstractions by smallholder irrigators are neither controlled, nor have incentives to use water efficiently.

In theory a person or community must have a water right to be allowed to take water from a pump or irrigation ‘furrow’. However, in general smallholder irrigators don’t hold water rights. Currently efforts are being made to persuade communities to accept them, but there is understandably resistance. Tanzania has a very long history (stretching back into pre-history) of indigenous irrigation, and people do not understand why they must now pay for a permit for something their ancestors have always seen as a right.

In order to manage water resource in the Rufiji Basin, the Rufiji Basin Water Office was established after the inauguration of the Basin Water Board in 1993. The main objectives of the office are firstly, to act as principal executors of the water Utilisation Act No. 42 of 1974 and its subsequent amendments (namely of 1981, 1989 and 1997) on water allocation and water pollution; and to carry out research pertaining to water resources management in the Rufiji River Basin.

The following are among the immediate plans of the Office:

- To update and establish a water rights and water abstractions register as per existing situation.
- To establish and maintain a water resources data bank for water management purposes.
- To carry out awareness creation activities and education to raise the communities' social and political will and commitment towards water resources management problems.
- To involve stakeholders in water resources management issues particularly those related to equitable utilization, allocation and conservation of water resources.
- To establish Water Users Association or Water User Groups as legal institutions linking the Office with stakeholders in all matters related to the management of water resources.
- To continue with water pollution monitoring and control and water apportioning in the basin
- To continue with monitoring, regulation and control of water resources
- In collaboration with other institutions, to facilitate environmental and water resources management issues in the basin.

Just like in the Pangani basin, several studies have shown how water scarcity has resulted in conflicts between different groups in the Rufiji basin (e.g. Baur et al 2000, Maganga and Juma, 2000, World Bank, 1997). In the Usangu Plains, water scarcity has resulted in conflicts between farmers and pastoralists, especially during the dry season. The rising number of cattle has increased the requirement for water and forage during the dry season, while at the same time the expansion of areas under irrigation by farmers has reduced the land area available for grazing. Pastoralists in turn drive their cattle on cultivated fields to access water sources during the dry season, causing damage to crops and cultivated fields.

Farmers in both Pangani and Rufiji basins view basin management suspiciously, and consider it as an effort to safeguard TANESCO's[3] interests in reserving sufficient water for hydropower (WORLD BANK, 1997). This negative perception is reinforced by the fact that TANESCO is providing most of the financial and material support for managing water resources in the two basins – creating an impression of inequitable use of water resources and inequitable sharing of benefits derived from using the basin water resources.

Again, domestic water issues are the focus of little consideration or concern, despite the large numbers of people without access to adequate supplies and the important contribution that domestic water makes to livelihoods (promoting economic activities as well as obvious health gains).

5.3 Current initiatives

As an outcome of the Rapid Water Resources Assessment, the World Bank agreed to fund two projects related to IWRM in the country: the River Basin Management (RBM) and Small Scale Irrigation Improvement (SSIP) projects which are in their 4th year of operation. The projects aim to strengthen government capacity to manage water resources using an integrated approach. Currently, there is a lack of co-ordination between these projects or with water supply and sanitation efforts such as the World Bank funded rural and small towns water supply and sanitation projects. However, the RBM project is reviewing water policy and institutional frameworks with an aim to improve this in the near future. In addition the projects are helping to rehabilitate the hydrometric networks in the two pilot basins to provide the necessary data to take management decisions.

6 CONCLUSIONS

This paper has reviewed the historical development of domestic water supplies in Tanzania, and attempted to account for some of the reasons for failure of water supply systems. It has considered

[3] Tanzania Electric Company, the power generating company

the water resource constraints faced in meeting the water supply needs of rural and urban populations, and the implications for integrated water resources management in the country. The paper has highlighted the problems of supply-driven WSS. These problems include insufficient coverage, high cost and poor utilization.

The major challenges for the improvement of WSS in Tanzania continue to be to ensure adequate investment in appropriate infrastructure and ensuring operation and maintenance of water supply systems. Nonetheless the complete failure to date of so called IWRM projects to deal with WSS, or to try to bring together the different actors in water for food, water for people, and water for the environment is disappointing. This failure risks becoming yet one more factor in the already long list that lead to the failure of domestic water systems. It must be noted that:

- none of the water resources programmes in Tanzania deal explicitly with WSS needs, and the sector must become more actively involved in IWRM fora in order to ensure that its interests, and the livelihoods of the poor in particular, are promoted.
- there are important differences in perceptions between irrigation and water resource professionals on the one hand and WSS professionals on the other. The former tend not see the need to include the 'small' amounts of water needed for WSS in their considerations, as this has 'no impact' on the overall water resources situation and is covered by different departments. WSS professionals however recognise the impacts that other uses have, or have the potential to impact in the future, on the access of people to WSS.
- current water resource programmes take little account of groundwater – seen as the 'drinking resource' and the remit of others. Even where rural people use irrigation furrows for mixed use the attitude is often that they shouldn't, and that once the 'WSS people' have developed groundwater supplies, they would cease to do so.

7 ACKNOWLEDGEMENTS

This paper was prepared as a contribution to the research project, Water, Households and Rural Livelihoods. The WHIRL project (http://www.nri.org/WSS-IWRM/) is supported by the UK Department for International Development (DFID) through the Infrastructure and Urban Development Division's Knowledge and Research programme. Project R7804 'Integrating drinking water needs in watershed projects'.

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More than a headcount: Towards strategic stakeholder representation in river basin management in South Africa and Zimbabwe

Emmanuel MANZUNGU

Department of Soil Science and Agricultural Engineering, University of Zimbabwe, P.O Box MP167, Mt Pleasant, Harare, Zimbabwe

zimwesi@africaonline.co.zw

ABSTRACT

In 1998 both South Africa and Zimbabwe promulgated new water laws to ensure that ownership and user-ship patterns of water resources matches the new socio-political order. Integrated water resource management, incorporating among other things decentralized and democratized water management institutions and the principles of stakeholder participation, was regarded as the cornerstone of the reforms. This article examines how stakeholder representation, particularly of the formerly disadvantaged people, has been handled. It is observed that there has been too much effort dedicated to ensure a mere headcount of the stakeholders at the water table rather than on strategic representation. Strategic representation emphasizes stakeholder identity instead of consensus. Selective alliance building is important as is establishing genuine local level platforms with enough political space outside the state-tailored formal straight jackets. It is equally important to address developmental aspects of establishing catchment-wide bodies and structural problems such as access to land and financial resources. Without addressing these issues stakeholder representation will remain hamstrung in good intentions.

Key words: *headcount; river basin management; strategic stakeholder representation; South Africa; Zimbabwe*

1. INTRODUCTION

In 1998 both South Africa and Zimbabwe promulgated new water laws, that among other things, sought to democratize water access and utilization, as a measure to correct racially informed social injustices of the past. Both countries, because of their history, are characterized by huge income inequalities, generally in favour of a white minority population ahead of the black majority. In Zimbabwe the purchasing power parity (PPP) of the poorest 20% of the population between 1980-1994 was 420, while that of the richest 20% was 6, 542. In South Africa the figures were cited as 516 and 9, 897 respectively (SADC Regional Human Development Report, 2000). This situation obtains because white settler regimes used political power to entrench national resources, particularly land and water, in white hands to the disadvantage of the native black majority population. As a consequence, in both countries, white-owned farms and estates use over 80% of agricultural water.

The collapse of the white minority governments in 1980 in Zimbabwe and 1994 in South Africa saw post-colonial governments seeking to reverse ownership and user-ship patterns of the natural resources, including water, to match the new socio-political order. Consequently water reforms were initiated in the 1990s culminating in the promulgation of the National Water Act (No. 36 of 1998) in South Africa and the Water Act [Chapter 20: 24 of 1998] in Zimbabwe.[1] Integrated water resource

[1] While there are some historical similarities between the two countries it is important to state that there are some differences. While South Africa embarked on water reforms immediately after the 1994 democratic elections Zimbabwe embarked on water reforms close to 20 years after independence (Manzungu 2001) more as a knee jerk reaction to the 1991/1992 worst drought in living memory.

management, incorporating among other things decentralized and democratized water management institutions and the principle of stakeholder participation, was regarded as the cornerstone of the reforms.

The situation briefly sketched above explains why the water reforms emphasize democratization of water management institutions. These institutions, based on river basins rather than on political-administrative boundaries, are called catchment management agencies (CMAs) in South Africa and catchment councils (CCs) in Zimbabwe, and are in the process of being established in the former and have been partially established in latter. They are regarded as all-inclusive platforms to bring about water democracy. This paper examines the process and modalities of how these new democratic water management institutions are being set up. The paper focuses on the proposals and practice of ensuring *strategic stakeholder representation* in the catchment-wide bodies, especially with regards to the formerly disadvantaged people. This draws upon Edmunds and Wollenberg (2001) 's strategic approach to negotiations in natural resources management. The authors suggest that approaches that try to underplay or neutralize differences among stakeholders through the pursuit of consensus and emphasis of communication for example, serve no strategic interests to disadvantaged groups/people. Rather strategic action should be emphasized. This may take the form of a) recognizing and promoting group identity of different water users as well as creating real political space for such groups to exist and operate and b) nurturing group interests and safeguarding them rather than emphasize vague notions of the common good. This may involve exercising the opt-out option through non-participation so as to de-legitimize a defective process. The challenge is to ensure that the structures are truly representative so that group interests are not compromised during interactions with other stakeholders and within the group itself. Surrogate representatives such local elites and community leaders can pose a danger. Selective alliance building, that sees merit in linking up with people in similar situations and genuine supporters, is another useful instrument in the quiver of arrows of those trying to seek greater water justice.

This paper observes that in both South Africa and Zimbabwe one notices much effort directed towards crafting multi-sectoral representation in river basin institutions that should “reach consensus” on water resources management. This can be gleaned from efforts devoted to ensuring a headcount of all stakeholders at the negotiating water table. This paper explores why this does not hold much promise, particularly at the local level, *vis-a-vis* the original objectives of the water reforms of empowering the formerly disadvantaged people. The substance of the argument is that to look for consensus and to exalt participation and communication, illustrates a deep theoretical poverty regarding the subtleties of the power dynamics involved in natural resource management.

The interrogation of the degree or level of stakeholder participation in the new water institutions in South Africa and Zimbabwe is important if not crucial. In South Africa substantive stakeholder representation rather than a mere participation is proving elusive despite efforts at social mobilization and transformation (Wester et al, 2001). In Zimbabwe the same situation has been reported (Manzungu et al, 1999; Derman at al, 2000; Sithole, 2000). This is despite claims in both instances of wide consultations during the pre-enactment period of the water laws. The implementation of the new water laws has not helped either. Some 75% of the black emerging farmers in the Inkomati basin in South Africa were reported to be unaware of the reforms (Waalewijn, personal communication). Wester, et al (2001) report similar ignorance in the Olifants basin. A similar situation was also reported in Zimbabwe (e.g..Sithole, 2000).

The claim of comprehensive and wide participation, which on current evidence has not translated into better knowledge, understanding and concomitant pro-reform action by the ‘beneficiaries’ of the reforms, is a paradox that must be explained. Since water management is a political issue, which deals with control and power (Wester et, 2001) it is important that policy implementers understand how power is wielded and yielded (Villareal, 1994, This will allow appropriate measures to make a reality the objective of the reforms. Mere postponement the establishment of the institutions until there is a 'correct' demographic balance as is happening in South Africa will not change the situation. The quick establishment of catchment and sub-catchment institutions in Zimbabwe, without ensuring sufficient political space for the disadvantaged, does not help either.

The evidence in this paper was obtained from official documents. Further evidence was also gathered from the author's research contacts in the Inkomati Basin in South Africa and the Save Catchment Council in Zimbabwe where the author has been undertaking research. Anecdotal evidence is also provided from general events in the two countries. Because of lack of space not many details will be provided in this paper.

2. ESTABLISHMENT OF RIVER BASIN INSTITUTIONS IN THE LAW

This section presents brief details of how the water reform in both countries is supposed to be undertaken according to the law. This precedes a presentation of the practice of the water reform process to date in the next section.

South Africa

Among other things, the preamble to the National water Act provides for a framework, in the form of national water resource strategy, within which water will be managed at regional or catchment level in defined water management areas. Some of the contents a national water resource strategy should have are given as to:

- Provide for the progressive establishment of catchment management agencies
- Establish water management areas and determine their boundaries
- Contain objectives for the establishment of institutions to undertake water resource management
- Determine the inter-relationship between institutions involved in water reserve management.

Chapter 7 of the Water Act provides for the establishment of catchment management agencies (CMAs) in a progressive manner through the authority of the minister. The most important thing to note is that a catchment management agency can be set up by way of proposal by an interested party or by a ministerial directive. The setting up of the CMA should illustrate that a process of public participation within the relevant water management area was undertaken. This should be captured in the proposal. In the absence of such a proposal the minister may establish a CMA on his own initiative. The idea of the whole process is to delegate water resource management to the regional or catchment level and to involve local communities within the framework of the national water resource strategy. The law provides that different types of advisory committees can be put in place before the establishment of the CMA. The Department of Water Affairs and Forestry (DWAF) responsible for water development in the country, can act as the CMA where one has not been established.

For a CMA proposal to be accepted the following should be satisfied:

- A proposed name must be proffered as well as description of the water management area
- Description of the status and significant water resources
- Proposed functions of the CMA , including functions to be assigned and delegated to it
- Funding of the CMAs must be indicated

- Indication whether there has been consultation in developing the proposal and the results of the public consultation process.

The Director General of DWAF may assist a person to develop such a proposal. DWAF reviews the proposal and makes a decision of whether to accept or reject it and then makes recommendation to the minister. The minister may conditionally accept the proposal pending clarification and correction of deficiencies. DWAF has produced guidelines for evaluation of the proposals.

The functions of CMAs in the initial stages are given as to:

- Investigate and advise interests on issues relating to water resource management
- Develop a catchment management strategy
- Promote the coordination of the implementation of the strategy with the implementation of any applicable development plan established in terms of the water services Act (Act no 108 of 1977)
- Promote community participation in water resource.

A governing board will be instituted in such a way that the interests of the various stakeholders are represented and the necessary expertise for its operation is included. Members of the board can be elected or nominated by the different user groups for appointment by the minister. The minister must disclose reasons not to appoint a nominee. The minister may appoint further members and remove members for a good reason. It is also provided that local government should be represented. Further the minister may appoint members to:

- Represent or reflect interests as recommended by the advisory committee
- Ensure sufficient gender representation
- Achieve sufficient demographic representation
- Achieve representation of DWAF
- Achieve representation of the disadvantaged persons or communities that have been prejudiced by past racial gender discrimination in relation to access to water.

The CMA may also appoint committees. These are can be either geographical and specialist committees.

Water users associations (WUAs) are provided in Chapter 8. They are cooperative associations of individual water users who wish to undertake water-related activities for their mutual benefit. They are also a mechanism through which a CMA can devolve implementation aspects of a catchment management strategy for the area it operates in (DWAF, 1999). The evidence will show later that the implied voluntary membership of the WUAs underlining the spirit of free association as expressed in the Act is in practice being violated by the insistence on multi-sectoral entities.

Zimbabwe

In the Zimbabwean context water resource management is the joint responsibility of the Zimbabwe National Water Authority (ZINWA), a parastatal that took over the operational functions of the Department of Water Development (DWD) and the Regional Water Authority (RWA) which operated in the southeastern part of the country. Under the new arrangement DWD has retained policy and legal functions. Two pilot catchments, Mazowe and Sanyati (which started as the Mupfure) funded by the German and Dutch respectively were started with the purpose of incorporating the experiences in the Water Act.

With regards to catchment councils or river basins, their existence and functioning are given in the Water Act. Part 3 of the Water Act entitled 'Water Resources Planning and Development' provides for the establishment of catchment management bodies known as catchment councils:

> A river system shall be under control of a catchment council, which shall be subjected to the supervision of the Zimbabwe National Water Authority.

For ensuring the optimum development and utilization of water reserves in the country ZINWA and the concerned catchment council in any river basin shall prepare a catchment outline plan in consultation with authorities and bodies who are likely to have interests in development of the catchment area (significantly individuals are not included). They are also required to draw up an inventory of water resources in a catchment. Catchment outline plans should:

- Indicate major water uses
- Proportion of the potential yield allocated to different water uses
- Indicate maximum permissible levels of exploitation of water and relevant quality standards
- Phasing of any development and priority of that proposed development
- State the relationship of the development proposals and with neighboring river systems
- Identify reserved areas for dams and water for future use and benefit for the environment
- Indicate priorities in utilization and allocation of water taking into account policy guidelines provided by the minister
- Provide for changes in priorities of use due to availability of water or social or economical priorities.

The plan shall be forwarded by ZINWA to the Secretary of the Ministry of Water for examination and recommendation. The secretary has the power to gather more evidence, revise or amend the plan. The plans are subject to review after 10 years. The minister in consultation with ZINWA may draw the boundary, stipulate the number of members and assign a name o the catchment council. The functions of Catchment Councils are to:

- Prepare an outline plan
- Determine applications and grant permits
- Regulate and supervise exercise of water rights
- Supervise performance of sub catchment councils.

The process of establishing sub-catchment councils is virtually the same as those of catchment councils. The major differences between the catchment and sub-catchment councils are that the catchment councils are more like company boards in that they do not have operational responsibilities unlike sub-catchement councils. For example CCs have no power to levy water users as sub-catchment councils can do. Catchment councils also do not have a budget of their own – they function according to a budget provision from the Water Fund. Catchment councils can, however, delegate any function to sub-catchment councils except the responsibility of issuing water permits.

3. ESTABLISHING CATCHMENT-WIDE BODIES IN PRACTICE

After examining what the legislation says about how catchment-wide institutions should be set up this section examines what the practice has been to date. One of the first steps in both countries was to draw up boundaries of the jurisdiction of the catchment wide bodies. In South Africa the country was divided into 19 water management areas. Zimbabwe was divided into 7 catchment councils.

South Africa

The Inkomati Basin in South Africa is the first basin where a proposal for the establishment of the CMA in accordance with the National Water Act was produced. The basin is reportedly over-exploited in terms of water use to the extent that DWAF has instructed that no further water licenses should be issued. This may be the reason why the basin was chosen as a pilot study.

The DWAF regional office, Mpumalanga, was the driving force behind the drafting of the proposal in two main ways. First, the office coordinated stakeholder consultation. The consultation was on a sector basis and also on forums that brought together all the stakeholders. The consultation was among the lines of the major tributaries, namely the Komati, Crocodile and Sabie. These consultations culminated in the Inkomati reference group. Second the DWAF office also contracted a team of consultants to oversee the writing of the proposal. In this exercise the consultants were required to consult with stakeholders as much as is possible.

Although the proposal was drafted under the auspices of the reference group there were some disagreements among the various parties involved. For example the Malelane Cane Growers Association representing 21 500 hectares of irrigated land in the Nkomati Water Management Area and farmed by 83 commercial and 370 emerging (black) farmers objected to the proposal regarding representation and financing aspects relating to the possibility of a large bureaucracy which could be avoided by delegating functions to existing bodies *vis-à-vis* the soon to be transformed irrigation boards[2]. The national power utility, Eskom, echoed the same sentiments of the need for a cost-effective structure and added that salaries of staff of CMAS should be in line with the public sector[3].

The proposal was rejected by DWAF head office principally on the grounds that there was no evidence of public participation. The proposal could be re-submitted once the deficiency was attended to. Meanwhile the stakeholders seem frustrated by the stalled process, which is now over a year old. At the moment there is confusion regarding the proposal. DWAF regional office awaits reaction from the head office while the head office awaits the regional office. The evaluation of the proposal itself seems to have been caught up in the ever-developing paper mill of guidelines of evaluating CMA proposals. Some stakeholders would like to see an interim structure to be set up so that the momentum not be lost. In the meantime the DWAF regional office is driving the process of writing a catchment management strategy. Again consultants will do the actual day-to-day work with stakeholders being consulted. DWAF is of the opinion that it is within its legal entitlement to do so and is prepared to risk leaving some stakeholders aside. DWAF seems to work with a worst case scenario where the newly established CMA when established may have to come up with its own catchment management strategy.

The proposals of irrigation boards to transform into water user associations in line with the Water Act i.e. 6 months after the promulgation of the Act, were also turned down by DWAF. The reason was that there was not enough consultation of all interested parties. DWAF insisted on multi-sectoral water users associations with all stakeholders coming under one roof. Some stakeholders have expressed misgivings about this arrangement saying it will be unworkable. This is an understandable point given the huge number of stakeholders involved. A suggestion has been to have committees of various

[2] P.W. De Wet letter to Mr Haroon Karodia, 7 September 2000.
[3] Rob Lines letter to chairman ofd Komati River Irrigation Board. 25 November 1999.

water users with the WUAs providing an umbrella body which meets say quarterly to receive reports of the various committees. There are other issues at stake as can be seen in Box 1.

Box 1: The representation question

§ In the Northern Province black smallholder farmers irrigating from a river shared by white commercial farmers do not want to form a Water Users Association that includes white farmers. They want their own organization. DWAF objected on the grounds that this was against the law and the spirit of the reforms. Allowing this would be a signal of a return to apartheid days of separate development. Besides there would be too many organizations that would be difficult to administer. The farmers stood firm. In the end DWAF conceded on the understanding they would still be part and parcel of a WUA that would bring them and white farmers together.

§ Black smallholder sugar cane farmers now constitute 50% of the irrigation board in the Lower Inkomati River. The chairman is a white manager and is deputized by a black farmer, which is often the case in many boards. The secretary is usually a white lady inherited from the old irrigation board. The black farmers have frequently complained against her and want her dismissed but this has not happened. Black farmers do not get sufficient water to their plots. They see this as a consequence of Eskom, which has diverted water from the basin for electricity generation. They also blame Swaziland, which is said to take more than its share. They praised the chairman for doing a lot to change the situation, which unfortunately did not materialize. The black farmers do not seem to see that the white farmers with whom they are sitting at the table do hold water that can be re-allocated to them.

§ In the Mangwane area drinking water is unreliable. This is due to inadequate capacity at the reservoir and also because of the new institutional changes regarding water supply. Water piracy is rife even by government officials including police officers. Technicians realise this is a social problem which needs to be addressed by ‘training’. There is, however, no platform for this sort of situation.

§ The Solani Trust has a 200 ha and irrigates 80 ha. It irrigates below its provision because of a lack o financial resources to buy equipment. Yields are low to the extent that the Transvaal Sugar Board has threatened to cancel the quota. Access to information is said to be unavailable.

Zimbabwe

The minister through his officials went around the country to establish all the catchments in 1999. The various stakeholders had been given a word to choose representatives to the sub-catchments and catchments. The process of choosing the representatives of stakeholders aims to have in place sectoral representation i.e. every sector is supposed to be represented as in Table 1.

Table 1: Stakeholders of sub and catchment councils

Stakeholder	No of representatives
Commercial Farmers Union (Large scale white farmers)	2 or 3
Zimbabwe Farmers Union (smallholder farmers)	2 or 3
Indigenous Commercial Farmers Union	1
Forestry	1
Mining	1
Rural district council (councillors)	1or 2
Traditional leaders	1 or 2
Urban	1
Small scale irrigators	1

At the sub-catchment council level members should not be more that 15. This was a compromise after the earlier calls for representation according to amount of water used which was not in line with demographic factors (Manzungu et al, 1999).

To date the Save catchment council has put in place mechanisms with the approval of the official regulations relating to

- Application for water permits
- Payment schedule for water related services offend by the council
- Management structures e.g. a small sectoral that includes a training officer.

Catchment and sub-catchment council meetings are held once every month where a variety of issues are discussed. There are, however, a number of problems that have affected the process. They are briefly described below.

The elections to the various positions in the catchment council itself and sub-catchments produced interesting results. Despite their numerical inferiority white farmers managed to place themselves strategically by winning the chairmanship. The deputy chairman was black person. This mirrors the problems of transition for all the catchment councils throughout the country.

In areas where river boards used to exist the sub-catchments tend to be chaired by a person who held a senior position in the river board. Invariably the secretary used to do the same under the river basin structure. In rural areas one sees local elites be they political or otherwise being chosen into positions. In the case of the Odzi sub-catchment the first deputy chairman, who was elected on the Zimbabwe Farmers Union, did not even come from the area. This is a widespread practice where rural people are said to be represented by ZFU. This is an anomaly since not all rural people are members of the ZFU. Political councillors have also dominated the meetings through the Rural District Councils (RDCs).

The net result is that the people who use water do not feature at all at the representation fora. This is illustrated by the fact that there are few to no women in the councils. There is evidence that the so-called representatives do not report back to the people that they are supposed to represent. Stakeholder identification is rather limited in and is based on organizations defined the state. Some of the organizations, such as the ZFU has been reported to have no local membership. Local organizations and local interests tend to be subsumed in other structures that do not address their real needs. There are no local platforms for local interests to be examined.

It has been noted that attendance at the meetings by the rural people tends to be erratic and those that attended tend to make few if any contributions. The same situation was worse when there was no money set aside to cater for transportation and accommodation. The situation has somewhat improved with the availability of funds from some donor. This, however, has created problems. It has been observed that some councilors are only interested in getting the allowances. A similar scenario has been reported in South Africa.

The lack of adequate information among rural people is common. For example at a meeting of the Upper Save sub-catchment in August, practically all the councillors had not had sight of the Water Act, the very basis of their existence. The fact that the law in in English has not helped the situation. This has put many people at a disadvantage. Frequently rural people are accused of not understanding that catchment councils are not about water supply but about water resource management. However, the situation of these people makes it natural for them to want to talk about water supply rather than the abstract concept of water resource management. Indeed the continued participation of the rural people rests on their felt needs being addressed.

There is at play a commercialization versus development dilemma. Manzungu (2001) has observed that Zimbabwe 's water reform is torn between economic-technical and social objectives and lacked provision of strong local institutions to further the democratic ideals of the water reforms. The fact that an application form to apply for a water permit costs Z$2, 000 (US$40) also to be paid by poor communities raises fundamental questions regarding the social viability of such a process. The fact that there are no mechanisms to ensure developmental aspects of catchment e.g. information dissemination is a case in point. Limited stakeholder membership has not helped. To date the practice stakeholder is limited to a water user who abstracts water and therefore warrants representation is problematic. Structural problems relating access to land and financial resources add a compounding dimension. Without these resources there is no meaningful stake for the poor communities in the water sector. These are factors, while not directly linked to water reform, are important if water is to be used productively.

4. CONCLUSIONS

The evidence provided here is that stakeholder representation in water resource management in South Africa and Zimbabwe is fraught with many difficulties, which need to be addressed in both the short and long term. In both countries stakeholder identification in the water sector was weak, as it was fixated on organizations that in many cases do not represent the actual water users. Because *stakeholder analysis* was weak this allowed the process to be captured by elites of various descriptions. A related point on stakeholders is *identity*, which is an important issue in stakeholder representation. Black smallholder farmers in both South Africa and Zimbabwe appeared lost in the new organizations despite their numerical superiority. The black farmers were a stakeholder group that needed to protect its interest by having and maintaining its own identity first which has been compromised by the insistence on multi-sectoral institutions. There were no feedback meetings by the representatives, a situation made worse by the fact that there was often no budget for such activities.

Stakeholder identity allows strategic action by the various groups to protect their interests. For maximum effectiveness and as much as possible, local organizations should coincide with the social organization. To this extent there is no need to always place the organizations into formal straight jackets tailored by the state. It can therefore be concluded that a mere demographic balance does not remove the unequal access to water and that roundtable participation does not guaranteed results. This is because in multi-sectoral water user associations may subsume the interests of the less powerful, especially given the size of jurisdiction of some of the new water user associations where the command area runs into thousands of hectares.

Issues relating to water resource management cannot be separated from developmental aspects such as access to basic water supply and capacity building that is needed to ensure that rural people quickly learn the slippery water ropes. There cannot be any meaningful participation in water management without the linkage to drinking water availability as well as sanitation. There is also the issue of structural problems such as access to land and financial resources that need to be considered. Without access to these resources water reform will forever remain a pipe dream, which may in time cause some stakeholders to lose interest. The challenge is to ensure that the structures are truly representative so that group interests are not compromised during interactions with other stakeholders and within the groups itself as well as creating real political space for such groups to exist and operate as well as nurture group interests and safeguarding them rather than emphasize vague notions of the common good of water resource management.

This paper has suggested that strategic representation that emphasizes stakeholder identity instead of consensus is the key. Selective alliance building and establishing genuine local level platforms with enough political space outside the state-defined formal straight jackets cannot be over-emphasized. Addressing developmental aspects of establishing catchment-wide bodies and structural problems such as access to land and financial resources is an integral part of the process. Without addressing these issues stakeholder representation will remain hamstrung in good intentions

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The application of the two coupled models for water quality management: facultative pond cum constructed wetland models

D. A. MASHAURI[1] and S. KAYOMBO[2]

University of Dar es Salaam, Faculty of Engineering, P.O.Box 35131 Dar es Salaam, Tanzania

mashauri@ce.udsm.ac.tz

ABSTRACT

Recent work has emphasised the potential importance of the constructed wetland systems for purification of effluents from secondary biological treatment plants for prevention of pollution to the receiving water bodies. A model for transformation of organic carbon in facultative pond (FP) was formulated and was coupled with a model of organic carbon transformation in the constructed wetland (CW) for downstream water resources management. The main essence of coupling the model was to have simultaneous simulation of PFP and CW processes. Simultaneous run of the two models imply that the disturbance on parameters in PFP will have a direct effect on CW processes. The model was formulated on the basis fundamental principle that the growth of active biomass in the system defines the transformation of organic carbon. The growth rate of microorganisms was model based on the Monod kinetic equation. The forcing functions to the model were formulated based on multiplicative function. The removal of organic carbon in the FP based on the unfiltered sample was 66% with an average concentration of 206mg COD/l in the effluent. The removal of organic carbon in the CW was 87.5% with an average concentration of 40 mgCOD/L in the effluent. The overall performance of the coupled model was 93%. The main processes of organic carbon removal in the FP and CW were due to uptake by heterotrophic bacteria followed by oxidation. It was found that 80% of the total organic carbon in the CW was due to the biological growth. Oxidation of organic carbon in the PFP was a source of high growth of algae. The constants and coefficients obtained after validation of the model reflect the simultaneous performance of the coupled model of PFP and CW.

Keywords: *constructed wetlands; facultative ponds; coupled model; heterotrophic bacteria and algae biomass; organic carbon transformation;* Phragmites Mauritianus.

1. INTRODUCTION

Waste Stabilization Ponds (WSPs) are still regarded to be the most effective non-conventional method of sewage treatment in developing countries especially in hot climates due to; their outstanding efficiency in reducing pathogenic bacteria, and the ova of intestinal parasites responsible for the high level of mortality and morbidity. WSP usually can absorb both hydraulic and organic loading due to their long hydraulic retention times (Mara *et al.*, 1992). The process of oxidation of organic matter mainly is accomplished by bacteria on the presence of dissolved oxygen supplied by the process of photosynthesis.

Constructed wetlands (CWs) are planned systems designed and constructed to employ wetland vegetation to assist in treating wastewater in a more controlled environment than occurs in natural wetlands. Influent to constructed wetland may range from raw wastewater to secondary effluents. All wetland are attached growth biological reactors. Attached and suspended microbial growth is responsible for removal of soluble organic carbon. Organic compounds in the CW are degraded both aerobically and anaerobically and is difficulty to quantify the ratio between aerobic and anaerobic degradation (Vymazal, 1999). Ottava *et al*., (1997) found that the number of aerobic heterotrophic bacteria in wastewater entering the vegetated beds are higher than anaerobic ones but anaerobic bacteria prevail in the outflow water. The major source of DO in the CW is though diffusion from the atmosphere through the plant to the root zones and the inflow from PFP.

To design a facultative pond, three approaches are used, namely; based on empirical (Mara *et al.,* 1990; Middlebrooks *et al.,* 1982; MacGarry and Pescode, 1970), semi-empirical models (Ferrara and Herleman, 1981; Thirumurthi and Nashashiba, 1967; Hermann and Gloyna, 1958), and rational model (Marais, 1966). The rational design and performance calculations for treatment of wetland and WSPs often takes the form of first order removal equation for steady state operating conditions, supplemented with Arrhenius temperature dependence of the rate constant (k). Based on literature the range of temperature coefficient "θ" for design of WSP is between 0.967 and 1.104, while the rate of oxidation (k_{20}) at reference temperature of $20^{o}C$ is between 0.1 and 1.09 day^{-1}. The rate constant "k" does not indicate how much organic carbon is channelled to oxidation, growth and settling. Besides the temperature all other forcing functions are assumed minimum. The objective of this paper is to present the two linked models, which defines both the processes that take place in primary facultative pond and CW. The model that may be used to define the transformation of organic carbon based on the individual processes and not as lumped information on the removal.

2. CONCEPTUAL MODEL FOR TRANSFORMATION OF ORGANIC CARBON IN FP AND CW

The carbon transformation in the FP and CW is presented in Figure 1. The state variables for transformation of organic carbon in the FP are; organic carbon, carbon dioxide, algae and heterotrophic bacteria and dissolved oxygen. The processes modelled were: oxidation, photosynthesis, uptake of heterotrophic bacteria on organic carbon and sedimentation. The forcing functions which affects the processes in the facultative pond ecosystem are; temperature, pH, DO, quality of substrate and light intensity. The effluent from the FP is discharged to the CW for further treatment as shown in Figure1. The state variable to the CW are the heterotrophic bacteria, organic carbon, carbon dioxide and detritus. The processes defining the transformation of organic carbon in the CW are oxidation, uptake by heterotrophic bacteria, decomposition of detritus to carbon dioxide and sedimentation of dead organisms and suspended solids.

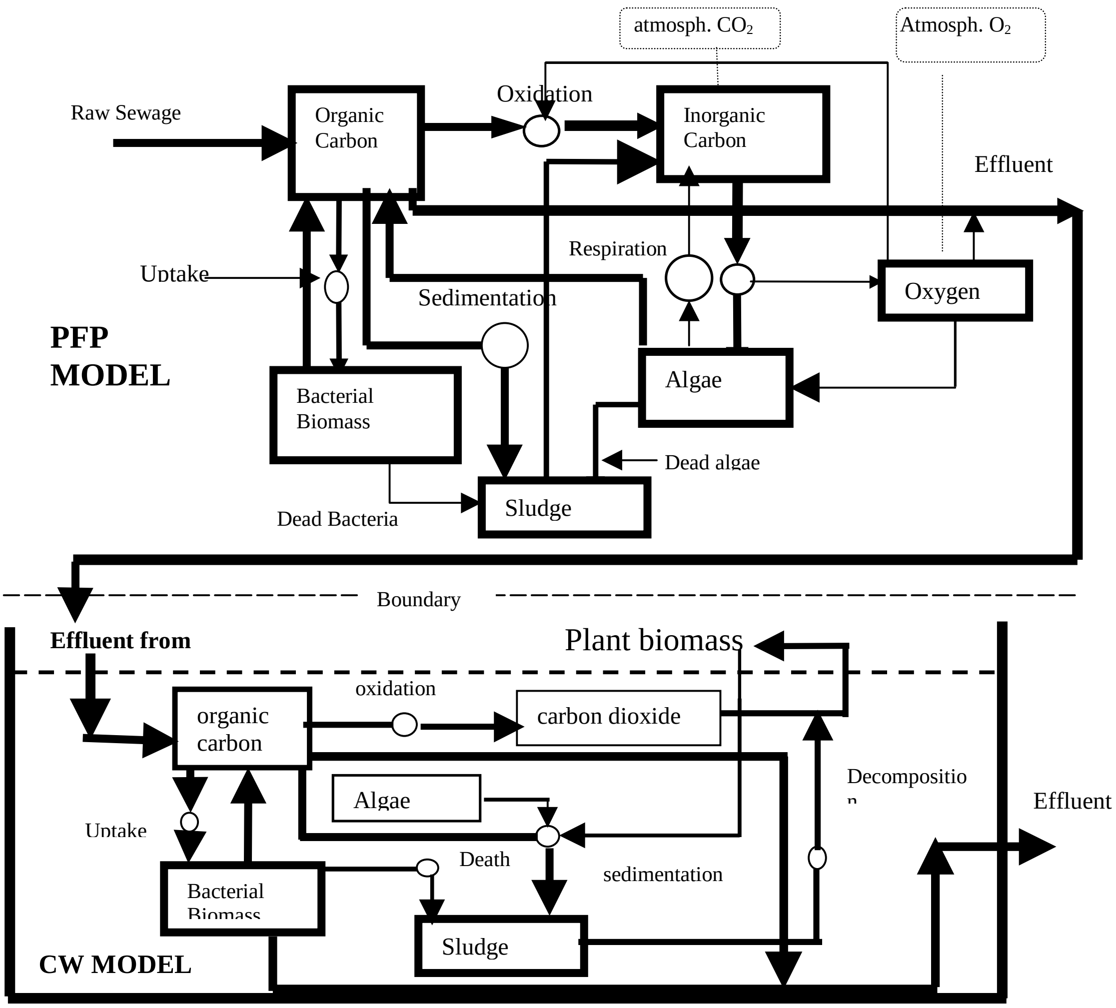

Figure 1 Conceptual model of carbon transformation in the PFP and CW.

2.1. Process Equation for Facultative Pond

The process equation for PFP is as presented in equation (1). The growth rate of algae and heterotrophic bacteria are modelled based on Monod kinetic equation. The forcing functions in the equation are formulated based on the multiplicative function.

$$\left(\frac{\partial OC}{\partial t}\right) = \left(\frac{Q_i C0D_i}{V}\right) - \left(\frac{\mu_{max(XB)} \frac{S_{COD}}{K_{SCOD} + S_{COD}} \frac{DO}{K_{SDO} + DO} \frac{K_{pH}}{K_{pH} - y} \exp\left(\kappa(T-20)\right)}{Y_{max}}\right) X_B - \left(\frac{Q_e COD_i}{V}\right)$$
$$- \left[k_{OX(20)} \theta^{(T-20)} \frac{DO}{K_{SDO} + DO}\right] COD + \left[\mu_{max(XA)} f(S.pH.T.L)\right] X_A + \left[\mu_{max(XB)} f(S.pH.T.DO)\right] X_B - \left[V_{S(XAB)} A\right] X_{AB}$$

Where, $\mu_{max(XA)}$, $\mu_{max(XB)}$ is the maximum growth rate of algae and heterotrophic bacteria (day^{-1}), K_{SCOD}, K_{SDO} and K_{SCO2} is the half saturation constant for organic carbon, dissolved oxygen and carbon dioxide (mg/l), Y_{max} is the substrate utilization rate (mgCOD/mg biomass), KpH is the pH constant, $V_{S(XAB)}$ is the settling rate of algae and heterotrophic bacteria, f(S,pH,T,L) is the function of substrate, pH, temperature and light intensity.

The first tem in equation (1) refers to the inflow organic carbon, the second term is the amount of organic carbon used by heterotrophic bacteria for growth, the third tem is the organic carbon in the effluent, the fourth term is the organic carbon oxidised to carbon dioxide. The growth of algae in the pond is presented in the equation (1) by the firth term. The growth rate of heterotrophic bacteria and the settling rate of algae and bacteria are presented in the sixth and seventh term in equation (1). The pH influence for the growth rate of algae and heterotrophic bacteria is as shown in equation (2)

$$\mu_{(XB)} = \mu_{\max(XB)}\left(\frac{K_{pH}}{K_{pH} + y}\right) \qquad (2)$$

$$y = 10^{|optpH - pH|} - 1 \qquad (3)$$

Where optpH is the optimum pH. The influence of light on the processes of photosynthesis is formulated based in equation (4)

$$\mu_{XA} = \mu_{\max(XA)}\frac{I}{IK + I} \qquad (4)$$

Where, I is the light intensity ($\mu E/m^2 s$) and IK is the half saturation constant for the temperature ($\mu E/m^2 s$). The influence of temperature on the growth rate of algae is formulated based on Jorgensen et al., (1978) and is shown in equation (5).

$$\mu_{XA} = \mu_{\max(XA)}\,\mathbf{exp}\left(-2.3\left|\frac{T - T_{opt}}{T_{opt} - T_{\min}}\right|\right) \; for \; T \le T_{opt} \; and \; f(T) = 1, \; for \; T \ge T_{opt} \qquad (5)$$

Where T_{min} and T_{opt} is the minimum and optimum temperature (^oC). The equation for the processes of production of DO in the pond based on the photosynthesis was adopted from Kayombo *et al.,* (2000) and is presented in equation (6) and in the fifth iterm equation (1).

$$PHOTO = \left[\mu_{\max(XA)}\frac{CO}{K_{SCO} + CO}\frac{I}{I + IK}\frac{K_{pH}}{K_{pH} + y}\,\mathbf{exp}\left[-2.3\left|\frac{T - T_{opt}}{T_{opt} - T_{\min}}\right|\right]\right]X_A \qquad (6)$$

The rate of settling of algae, heterotrophic bacteria and other suspended solids was modelled based on equation (7).

$$V_{S(XA)} = \frac{g(\rho_s - \rho)d^2}{18\mu} \qquad (7)$$

Where; $V_{S(XA)}$ is the settling velocity of algae (m/day), g is the acceleration due to gravity (m/s^2), ρ_s and ρ are the densities of solids and water (kg/m^3), μ is the dynamic viscosity of fluid (Ns/m^2) and d is the diameter of the particle (m). At average operating temperature the viscosity of fluid may be determined using equations (8) for $0^oC \le T \le 20^oC$ or equation (9) for $20^oC \le T \le 100^oC$.

$$\log \mu = \frac{1.301}{998.333 + 8.1855(T - 20) + 0.00585(T - 20)^2} \qquad (8)$$

$$\log\left(\frac{\mu}{\mu_{20}}\right) = \frac{1.3220(20 - T) - 0.001053(T - 20)^2}{T + 105} \qquad (9)$$

The diffusion of carbon dioxide from the surface to waste water in the pond is given by;

$$r.CO_2 = \frac{12}{44}k_{1co2}(CO_{2S} - CO_2) \qquad (10)$$

Where $r.CO_2$ is the rate of mass transfer of carbon dioxide to pond water, k_{1CO2} is the interfacial transfer coefficient, CO_{2S} is the saturation concentration of inorganic carbon (mg/l) and CO_2 is the concentration of inorganic carbon in the pond water. The interfacial transfer coefficient (K_{1CO2}) is defined for shallow lakes and lagoons as suggested by Blanks and Herrera, (1977) as follows;

$$k_{1co2} = \frac{1}{d}\left(0.384W^{0.5} - 0.088W + 0.0029W^{2}\right) \qquad (11)$$

Where; d is the pond depth (m) and W is the wind velocity (km/h). Hence the overall mass transfer of carbon dioxide to water is as shown in equation (12)

$$r.CO_2 = \frac{12A}{44V}\left[\frac{1}{d}\left(0.384W^{0.5} - 0.088W + 0.0029W^{2}\right)\right]\left[CO_{2S} - CO_2\right] \qquad (12)$$

Equations (10 to 12) were also used to determine the amount of dissolved oxygen diffusing from the atmosphere due to the effects of wind.

Regeneration of inorganic carbon from anaerobic zone

The sludge accumulation in the pond is due to sedimentation of dead cells of algae and heterotrophic bacteria. The mass balance of the sludge is expressed as;

$$\frac{dMS}{dt} = r_{1(ab)} + r_{2(g)} \qquad (13)$$

Where; MS is the active mass in the sludge (mg/m^2.day), $r_{1(ab)}$ is the volumetric reaction rate algal and bacteria sedimentation (mg/l.day) and $r_{2(g)}$ is volumetric reaction rate for regeneration from bentic layer (mg/l.day). The release of carbon dioxide from the sediment is expressed as

$$RC = U_r MS\left[0.358\,S_a + 0.531\,S_b\right] \qquad (14)$$

Where; RC is the regenerated inorganic carbon from the sludge (mg/cm^2.day), U_r is regeneration rate (day^{-1}), S_a and S_b is the fraction of algae and bacteria settling. The regeneration rate was determined using equation (15).

$$U_r = U_{r(20)}\beta^{(T-20)} \qquad (15)$$

$U_{r(20)}$ is the regeneration rate at 20^{o}C, (day^{-1}), β is the Arrhenius temperature constant

2.2. Model for the Transformation of Organic Carbon in the Constructed Wetland

The constructed wetlands are based on the design assumption of plug flow hydrodynamics and first order BOD_5 removal kinetics (USEPA, 1988, Burgoon *et al.*, 1995, Chen *et al.*, 1999) as shown in equation (16).

$$\frac{C_e}{C_O} = e^{-k_T t} \qquad where \qquad k_T = k_{20}\theta^{(T-20)} \qquad (16)$$

Where, C_o and C_e are the influent and effluent concentration (mg/l), k_T is the temperature dependent, first order rate constant (day^{-1}), and t is hydraulic residence time in the system (day). Based on the processes occurring in CW the overall equation for the transformation of organic carbon is as shown in equation (17).

$$\frac{dC}{dt} = \frac{Q_o C_e}{V} - r_{uptake} - r_{sed.} + r_{growth} - r_{oxid.} - \frac{Q_e C_e}{V} \qquad (17)$$

Where, r_{uptake} is the amount used by heterotrophic bacteria, $r_{sed.}$ is the organic carbon settling, r_{growth}, organic carbon generated due to growth, r_{oxid}. organic carbon oxidised to carbon dioxide (day^{-1}). The growth of heterotrophic bacteria in the CW, oxidation processes, settling of organic carbon, effects of forcing functions and the uptake by heterotrophic bacteria on organic carbon in the CW is formulated as shown in equation (1). The mass balance of organic carbon within the boundary of the CW will be as shown in equation (18)

$$\left(\frac{\partial OC}{\partial t}\right) = \left(\frac{Q_i C0D_i}{V}\right) - \left(\frac{\mu_{max(XB)} \frac{S_{COD}}{K_{SCOD}+S_{COD}} \frac{DO}{K_{SDO}+DO} \frac{K_{pH}}{K_{pH}-y} \mathbf{exp}\left(\kappa\left(T-20\right)\right)}{Y_{max}}\right) X_B - \left(\frac{Q_e COD_i}{V}\right)$$
$$- \left[k_{OX(20)}\theta^{(T-20)} \frac{DO}{K_{SDO}+DO}\right] COD + \left[\mu_{max(XB)} f\left(S.pH.T.DO\right)\right] X_B - \left[V_{S(XAB)} A\right] X_{AB}$$

The difference between equation (1) and equation (18), lies on the fact that the term on the growth rate of algae is not included but is only inclusive in the settling. The model was programmed using Stella II software. The overall model was then validated and calibrated using data from the FP and pilot scale CW planted with *Phragmites Mauritianus*. The agreement between measured and model predicted results were evaluated using linear regression analysis.

3. MATERIALS AND METHODS

Data for validation and calibration of the model were determined from the field pond systems and pilot subsurface flow constructed wetlands at the University of Dar es Salaam. The layout of the pond systems and CW are as shown in Figure 2. They are located at latitude 6^o48' S and longitude 39^o13' E. The mean monthly temperature varies between 23 and 28^oC. The ponds are used to treat domestic wastewater from the University of Dar es Salaam main campus that has a population of 5000. Four filed scale constructed wetlands were installed adjacent to PFP and are used for treatment of effluent from the PFP. The units were 11.0m long, 3.7 m wide and an overall depth of 1.0m. The effective depth packed with substrate was 0.6m. The substrate mix was 1:1:1 of ¼", ½" and ¾" respectively. Board gravels were packed at inlet and outlet occupying effective length of 2m. Hence the effective zone of treatment was 9m long. The average flow rate to CW unit was $2m^3$/day.

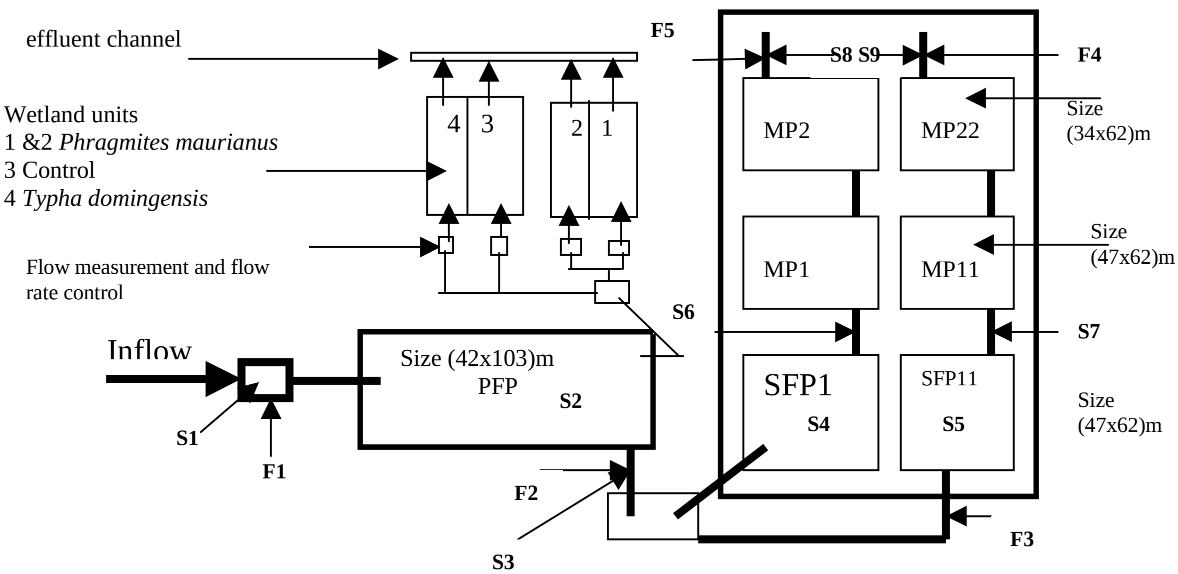

Figure 2. The layout of waste stabilization ponds and constructed wetlands at the University of Dar es Salaam. F1, F2, F3, F4 and F5 are the flow measuring points, S1, S2, S3, S4, S5, S6, S7, S8, and S9 are the sampling points. PFP and SFP is primary and secondary facultative ponds, MP is maturation pond.

3.1 Flow measurements, physical, chemical and biological analysis

Flow measurements were determined at the inlet and outlet of WSPs using triangular notches. The flow rate to the wetland units was measured manually using graduated beaker. Samples for determination of physical, chemical and biological parameters were collected at the inlet, outlets and in the system. Light intensity was measured by the use of datalogger model R10. The pH and temperature were determined in situ by Metrohom pH meter model 704, DO was measured using YSI DO meter model 95. The chemical and biological parameters were determined in accordance to standard method (American Public Health Association, 1992). The volatile biomass of heterotrophic bacteria was then obtained by the difference between the total biomass and algae volatile biomass.

RESULTS AND DISCUSSION

The average flow rate to the pond system at the University of Dar es Salaam was 489.70m^3/day. The outflow from the primary facultative pond was 443.9m^3/day indicating that loss due mainly to evaporation was 45.80m^3/day. The hydraulic characteristics of the pond and CW systems are as shown in Table1.

Table 1.Hydraulic characteristic of the units

Characteristic feature	unit	PFP	CW1	CW2	CW3	CW4
Surface area	m^2	5512.5	40.7	40.7	40.7	40.7
overall depth	m	1.92	1.0	1.0	1.0	1.0
Free board	m	0.38	0.4	0.4	0.4	0.4
Volume	m^3	10584	40.7	40.7	40.7	40.7
Average inflow	m^3/day	489.699	2	2	2	2
Operating retention time	days	22.00	5	5	5	5

Table 2. Average daily composition of influent and effluent for PFP, SFP1 and SFP11

Parameter	Units	Raw seage	PFP system	Effluent from PFP	Effluent from CW1	effluent from CW2	Effluent from CW3
TCOD	mg/l	611.8±34	273±66	249±82	44.95±20.22	31.90±13.40	35.35±22.26
SCOD	mg/l	478±56	200±74	156±59			
Carbon dioxide	mg/l	22±20	20±22	32±13			
Algal	µg/l chl-a		977±551	352±280			
Algal dry weight	mg/l		175±70	244±172			
Total bio-mass	mg/l		303±120	386±296	58.56±23.57	66.46±26.34	68.14±21.89
H.B	mg/l		127±51	162±124	58.56±23.57	66.46±26.34	68.14±21.89
pH		7.18±0.14	8.3±0.5	7.5±0.3	7.12±0.08	7.18±0.07	7.50±1.06
Temperature	^oC	30.0±1.12	31.3±1.4	30.3±0.9	27.73±1.14	25.34±0.45	27.44±1.06
Dissolved oxygen	mg/l	0.64±0.44	7.4±3.1	1.1±1.0	1.12±0.27	1.28±0.19	1.13±0.25

The performance of PFP on organic carbon removal based on filtered sample was 57%. The performance of the PFP couple with the CW based on the unfiltered COD was 93%.

3.1. Validation and Calibration of the Model Based on Data from PFP and CW.

Data from the PFP were used for the validation of the model based on the processes in the PF pond while data from constructed wetland 1 (CW1) were used for validation of the model based on the processes in the wetlands. Figure 3 and Figure 4 show the relationship between model predicted and measured organic carbon in the PFP and CW1. The linear regression between model prediction and measured organic carbon for PFP and CW1 yielded a coefficients of regression (R^2) of 0.54 and 0.59, respectively. The resulting constants and coefficients from the validation of PF and CW model are as shown in Table 3.

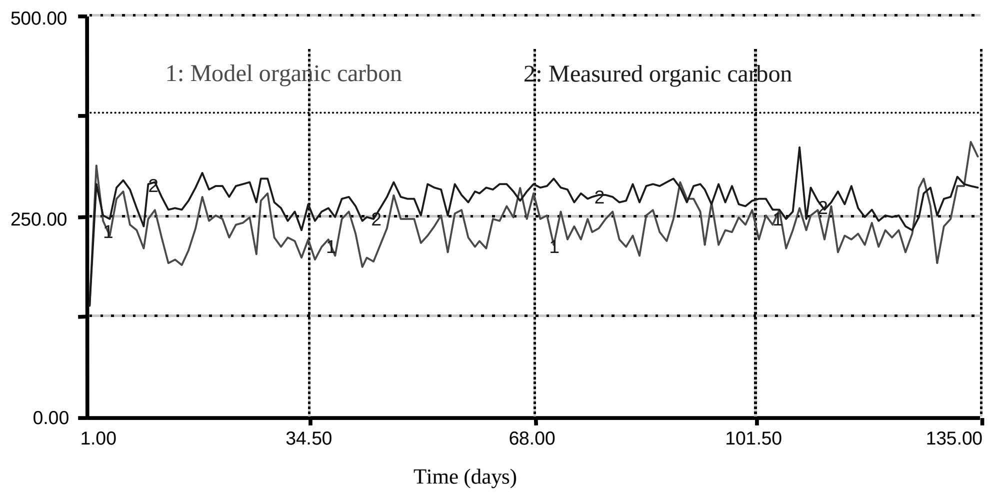

Figure 3. Measured and model predicted organic carbon in PF

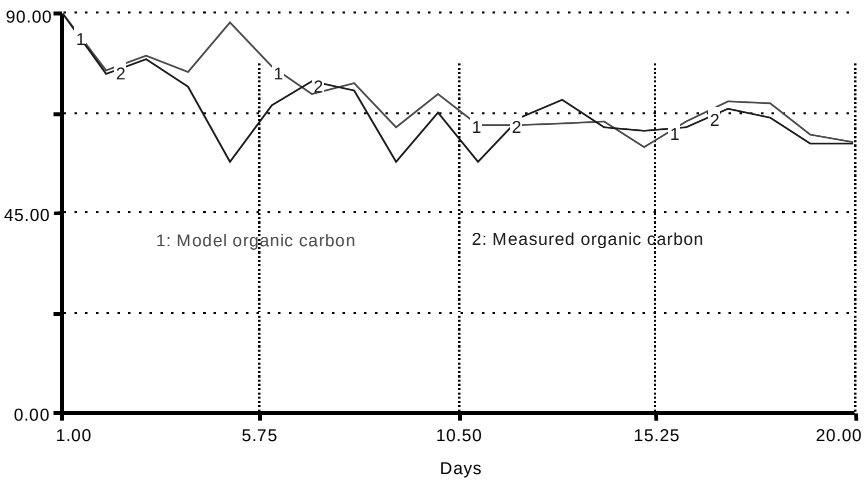

Figure 4. Measured and model predicted organic carbon in constructed wetland 1 (CW1)
Figure 5, 6 and 7 show the relationship between model predicted and measured heterotrophic bacteria and algae in PFP and CW1.

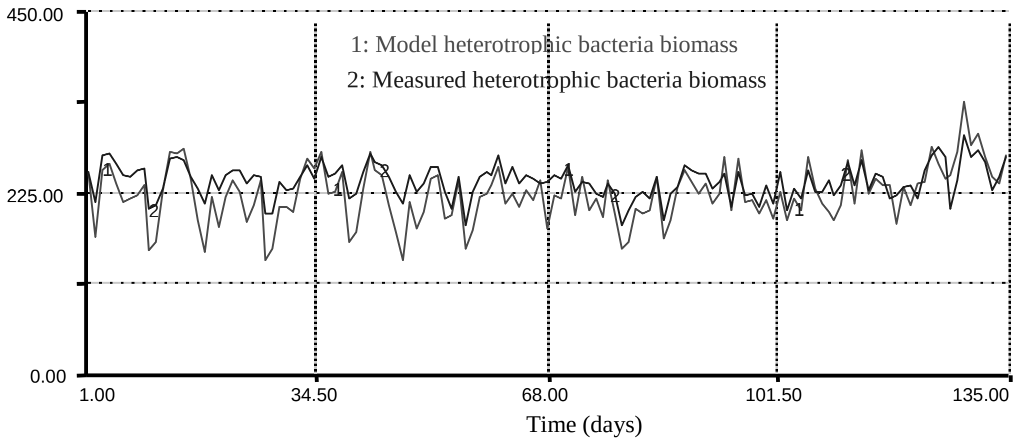

Figure 5 Measured and model predict heterotrophic bacteria in PFP

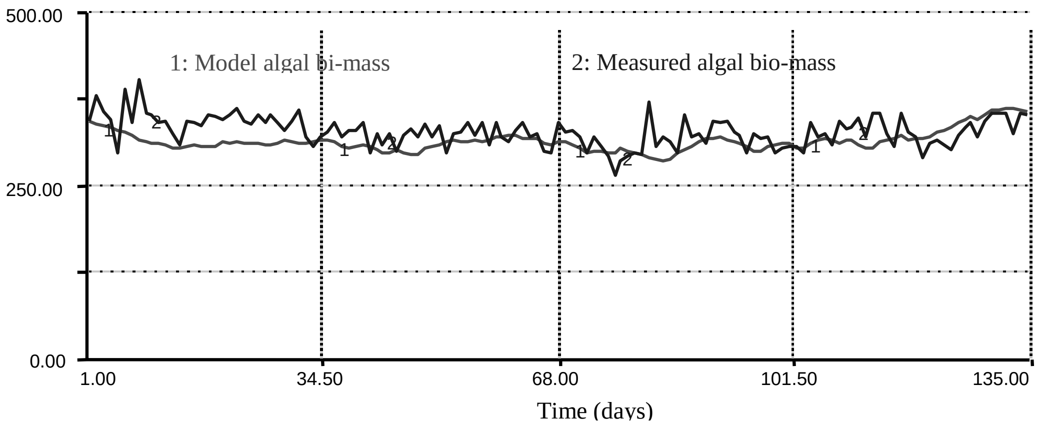

Figure 6. Measured and model predicted algal biomass in PFP

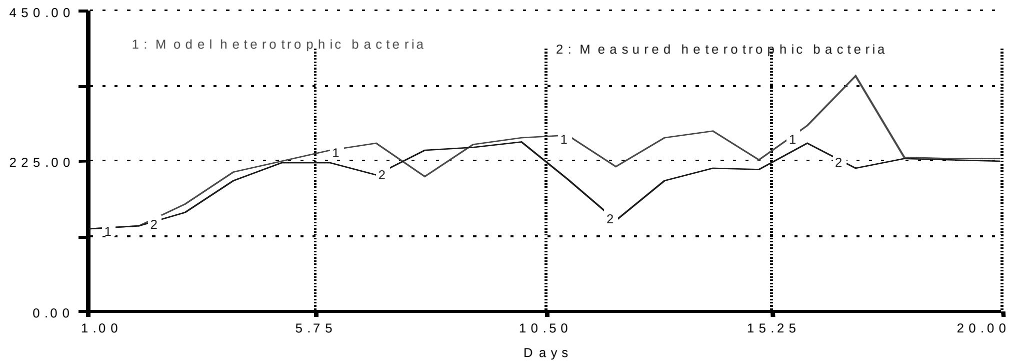

Figure 7. Measured and model predicted heterotrophic bacteria in CW1

The linear regression between model prediction and measured data on heterotrophic bacteria and algae yielded a coefficient (R^2) of 0.54 and 0.58 respectively. The linear regression coefficient (R^2) between measured and model predicted heterotrophic bacteria in the CW1 was 0.61. Figure 8 and Figure 9 show the mass balance on the transformation of the organic carbon in the FP and CW.

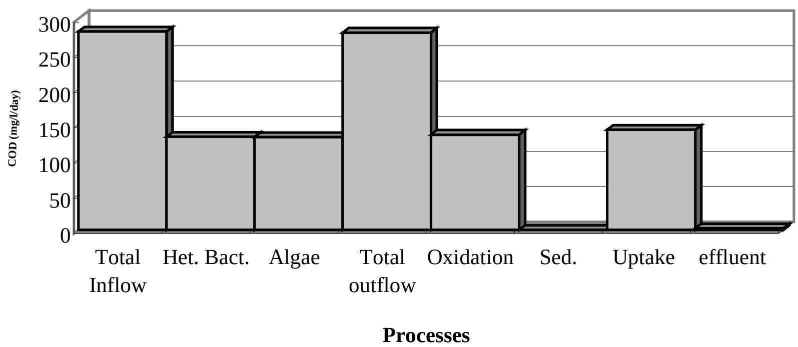

Figure8. Transformation routes of organic carbon in PFP

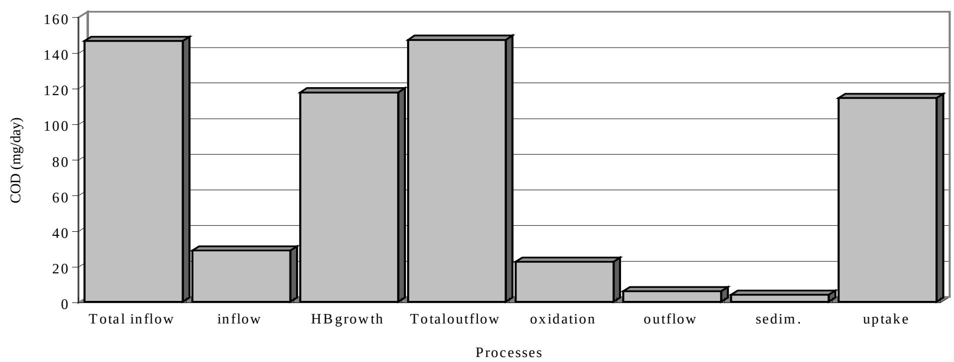

Figure 9. Transformation of organic carbon in the constructed wetland during validation

The results indicate that the main route of transformation of organic carbon in the CW and PFP is due to growth (uptake), followed by oxidation. Much of the organic carbon in the PFP was due to algae and bacteria biomass. In the CW, much of the organic carbon was due to bacterial growth. Organic carbon removal in CW due to uptake by heterotrophic bacteria was 77% of the total amount entering the system, followed by oxidation (15%).

Table 3. Values for validation and calibration of the model

Parameter	Units	Literature value	Validation PFP	Validation CW1	Sources
$\mu_{max\ (XB)}$	day^{-1}	3.8**	3.65	0.58	Laboratory
$\mu_{max\ (XA)}$	day^{-1}	2.7**	2.55	-	Laboratory
$\nu_{max(XA)}$	mg nutrient/mg algae	0.2 - 0.7	0.55	-	Jørgensen, 1976
Y_{max}	mg bio-mass/mg COD	0.788**	0.75	0.34	Laboratory
KpH(HB)		199**	136**	279	Laboratory
$K_{d(20)}$	day^{-1}	0.01 - 0.2	0.18	0.09	Henze et al. 1995
K_{SCO}	mg/l	0.5 – 0.6	0.50	-	Chen and Orlob, 1975
K_{SDO}	mg/l	0.1 - 1.0	0.9	0.08	Okabe et al. 1995
K_{SCOD}	mg/l	200**	185	55	Laboratory
pH opt (algae)		6.7**	7.79	-	Laboratory
pH opt. (HB)		8.5**	7.95	7.2	Laboratory
$R_{max(XA)}$	day^{-1}	0.03 – 0.92	0.43	0.58	Asaeda and Bon, 1997
κ (HB)	$^oC^{-1}$	0.06 - 0.1	0.04	0.14	Henze et al. 1995
Settling velocity (algae)	m/day	0.05 - 0.5	0.45	0.55	Fritz et al. 1979
Settling velocity (COD)	m/day	0.05 - 0.5	0.03	0.2	Fritz et al. 1979, Reed, 1990
β for regeneration	day^{-1}	1.07	1.07	1.06	Fritz et al. 1979
IK	$\mu E/m^2$	10 - 300	188	-	Asaeda and Bon, 1997
KpH (algae)		179**	189	-	Laboratory
$k_{OX(20)}$	day^{-1}	0.1 – 1.2	0.9	1.12	US – EPA, 1985, Reed et al., 1995
Ur(20)	day^{-1}	0.09	0.037	-	Foree and Jewell, 1970
S_a	day^{-1}	0.05	0.026	1.0	Canale, 1976
S_b	day^{-1}	0.05	0.006	0.004	Canale, 1976
β for decay		1.07	1.07	1.06	Fritz et al. 1979
T_{opt}	^oC		29	28	Model calibration
T_{min}	^oC		11	15	Model calibration

The calibration of the model for the CW was done by using data from CW2 when the coefficients and constants in Table 3 were kept constant. The relationship between model predicted and measured organic carbon and heterotrophic bacteria in CW2 is shown in Figure 10 and 11. The linear regression analysis between measured and model predicted organic carbon and heterotrophic bacteria in CW2 yielded a coefficient (R^2) of 0.56 and 0.66 respectively.

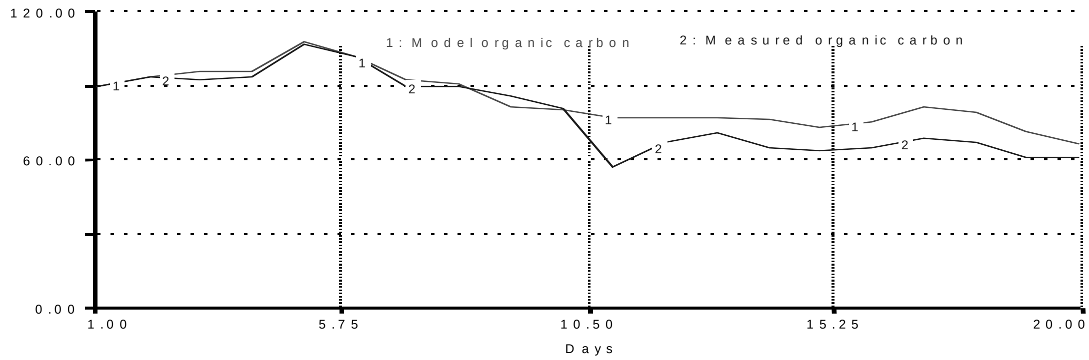

Figure10. Measured and model predicted organic carbon in CW2

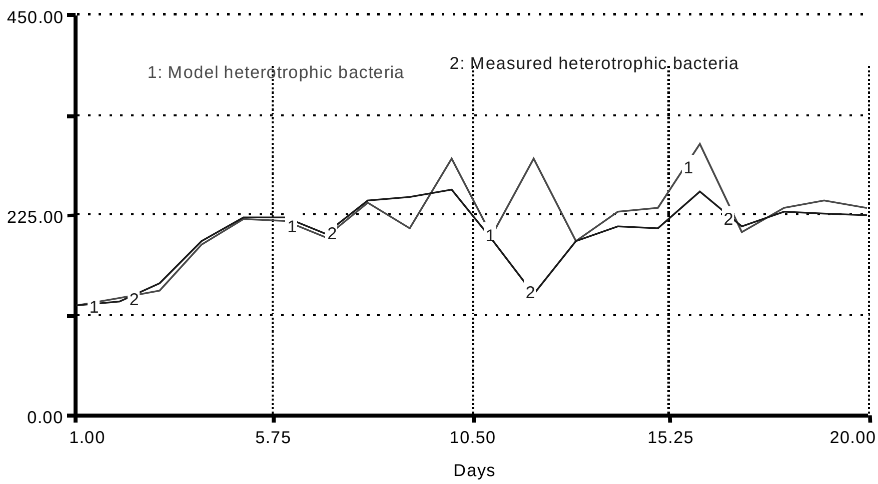

Figure11. Model predicted and measured heterotrophic bacteria in CW2.

Figure 12 shows the average transformation of organic carbon in the constructed wetland during the calibration of the model. The trend indicates that the process of uptake by heterotrophic bacteria was the main dominant route of the transformation of organic carbon in the CW.

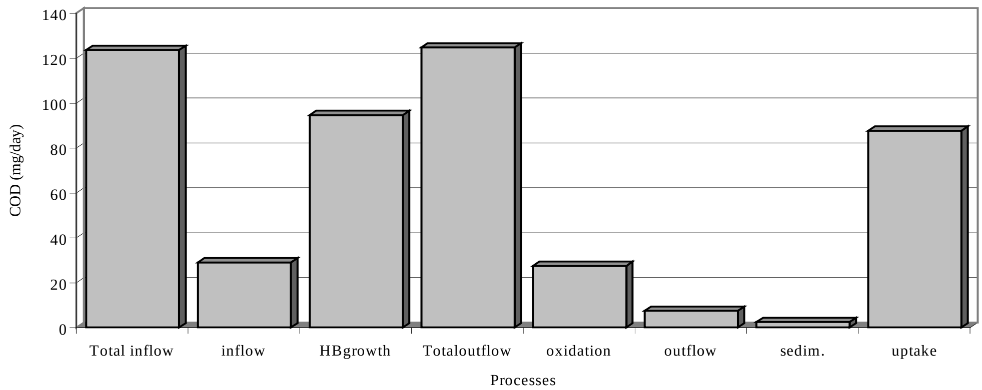

Figure 12. Carbon transformation in the constructed wetland during calibration of model

4. CONCLUSIONS

The coupled model for WSP and CW is formulated based on the growth rate kinetics described by Monod kinetic equation. This indicates that the processes in the pond and CW may well be defined by the Monod approach on substrate utilization and growth. The forcing functions both to PFP and CW affect the processes based on their multiplicative functions. The transformation of organic carbon in the PFP and CW are dominated by the process of uptake, which leads to high growth of heterotrophic bacteria in the systems. This was also revealed by the model on the amount of organic carbon which accumulate in the system resulting from the growth of the biomass. The model also revealed and quantified the amount of algae growing through the utilization of carbon dioxide resulting from the oxidation process in the pond.

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Groundwater management strategies and their implications on irrigated agriculture: the case of Dendron aquifer in Northern Province, South Africa

Mutsa MASIYANDIMA[1], Isobel VAN DER STOEP[2], Tendayi MWANASAWANI[2] and Shelton C. PFUPAJENA[2]

[1]International Water Management Institute (IWMI),141 Cresswell Street, Private Bag X813, Silverton 0127, Pretoria, South Africa
[2]University of Pretoria, Department of Civil and Bio-Systems Engineering, Pretoria

[1] m.masiyandima@cgiar.org

ABSTRACT

While groundwater is a small component of water resources in South Africa it plays a significant role in irrigation water supply at more localized scales. Aquifer yields are generally low, ranging from less than 1 to 20 l/s, with most of the aquifers yielding near to the lower end of the scale. The Dendron dolomitic aquifer in the Northern Province of South Africa is a high potential one by local standards, with yields of about 20 l/s. Some boreholes in the area yield much higher than the average 20l/s. The aquifer has been the sole source of irrigation water for commercial agriculture for more than 20 years. In the eighties groundwater levels were observed to be declining due to over-abstraction. This trend has continued to the present with current water levels averaging about 50 – 100 m below ground, a drop of more than 50 m in the last 30 years. In 1991 the Department of Water Affairs and Forestry informed farmers that a management strategy was required to ensure sustainable use of groundwater. Several steps to manage groundwater were taken. Although users are of the opinion that groundwater levels have been increasing, in fact the rate of groundwater level decrease has been increasing. This paper discusses the effect of cropping pattern and irrigation management changes on groundwater levels. The implications of different water management strategies on the sustainability of groundwater supported agriculture are analysed and recommendations made.

INTRODUCTION

The Dendron aquifer is an important source of irrigation water for the commercial agricultural activities in the Dendron area. In the last two decades there has been serious concern on the sustainability of the rates of groundwater in the long term. These concerns rose from the rapid expansion of irrigated area that has led to increased abstraction and a lowering of the groundwater levels by 5 to 35 m resulting from a rapid increase of irrigated area of over 170% between 1968 and 1986 (Northern Transvaal Cooperative, NTC, 1989). This increase in irrigated area resulted in a 133% increase in groundwater abstraction over the same period. As groundwater levels declined, boreholes dried and deeper ones were sunk in order to mitigate the problems of water shortages. In 1986 the Department of Water Affairs and Forestry (DWAF) issued a warning to the farmers that the aquifer could reliably supply water for a further 13 years only under the conditions that prevailed. In early 2001 the water levels were reported to be still low in some sub-catchments. Yet the aquifer still supports a substantial amount of irrigation. Some of the farmers say that the state of the aquifer has improved and that the water table has been rising in recent years. Some have simply shifted activities to sub-catchments that remain relatively unaffected by the severe over-abstraction. It is not apparent that any of the measures deliberately taken to reduce abstraction have achieved the intended objectives.

The main objective of this study is to make an analysis of the management of the Dendron aquifer and the impact this may have had on groundwater levels, and to establish the most effective methods of ensuring sustainable management of groundwater resources. Initially the available information on the aquifer and irrigation management is analysed. In the second phase, recharge to the aquifer will be modelled, taking into account the fractured nature of the aquifer and the variation of storage properties with depth.

Background

Continuous expansion of irrigated area in the Dendron area has been a major cause for concern among water users. In 1968 the total area irrigated with groundwater was about 1,319 hectares. About 9.3 million cubic meters of groundwater (or 4 % of rainfall) was abstracted to meet irrigation requirements. In 1974 irrigated area had increased to 1,474 hectares (Dziembowski, 1976). But abstraction levels decreased to 8.5 million cubic meters, a reduction of nearly 9 %. The period 1971 – 1975 was a high rainfall period during which groundwater levels were observed to increase by an average of over 0.25 m (Dziembowski, 1976). The recharge during this period was estimated at just under 4%. The cropping patterns during this period and the preceding one are not known. In 1986 irrigated area was about 3,579 hectares, more than double that of 1974. Water abstraction for irrigation, estimated using crop water requirements and cropped area, was about 21 million cubic meters.

Increased abstractions were met by mining groundwater. Over the years boreholes dried up, and new deeper boreholes were sunk to meet water demands. Groundwater mining was also evidenced in the unreliability of supply that ensued. The variability in the permanent delivery capacity of boreholes has been increasing (NTC, 1989.

At the initiative of the Pietersburg District Farmers' Union, the Northern Transvaal Co-operative (Division of Agricultural Development) and the Geohydrology Directorate of (DWAF), and with financial support of the Northern Transvaal Regional Services Council, a study was undertaken in the Dendron/Vivo areas in 1989. The aim of the study was to develop a groundwater management system for predicting the availability of groundwater available for irrigation on an ongoing and regular basis. Such a management system would enable water abstraction rates to be continuously and accurately monitored in order to prevent further overexploitation of the aquifer. The study covered the Doornlaagte catchment area and was later extended to the Brak and Hout River basins. While this study was never implemented fully, farmers, in response to the severe water table draw down and as part of the groundwater management strategy, agreed to irrigating only 3 % of total farm area. This means that for every 1 000 ha, only 30 can be irrigated. However, this rule does not apply to land that was under irrigation prior to the regulation was put in place (Cotzee, 2001). In addition to this irrigated area restriction, there has been a shift in irrigation methodologies. Farmers have shifted from furrow irrigation, to manual move sprinklers, and eventually center pivots. The motive for this shift was both to save water and to facilitate ease of operations (Cotzee, 2001). Some farmers have also made a shift from high to low pressure center pivot systems in order to save water. Another change was the shift from irrigating maize, a low value crop with high consumptive use of water, to high value crops such as potatoes. However, records of the changes in water abstraction have not been kept and can only be estimated from the cropping patterns.

Study area

The aquifer is located about 60 km north of Pietersburg in the Northern Province of South Africa (Figure 1), and lies in the Brakspruit and Hout river basins, both subcatchments of the Sand River basin that drains to the Northeast. The aerial extent of the aquifer is about 1,600 square kilometers. The area is generally flat and almost featureless. It is bound to the north by the Blouberg Mountains, and the Soutpansberg to the Northeast.

The Dendron area is characterised by summer rainfall. The rainfall season begins in November and lasts until March or April. The average annual rainfall is about 400 mm. Potential evapotranspiration is always much greater than precipitation and during average rainfall years, there is always a water deficit in the basin. Longterm trends of average rainfall and potential evaporation are shown in Figure 2.

The basin has two interdependent aquifers, a weathered upper aquifer and a lower fractured one (Jolly, 1986). A more detailed description of the aquifers is in Jolly (1986). The weathered aquifer is unconfined in some areas and semi-confined in others while the fractured lower aquifer is confined. The weathered upper aquifer has a storage coefficient of 0.01 while the lower one has a storage coefficient of 0.0025. The contact between the two aquifers is at 35 – 50 m below ground level. Groundwater yield in the aquifer is extremely variable, ranging from 0.1 to about 45 l/s. A significant proportion of the boreholes that are used for irrigation have yields less than 20 l/s. About 36% of boreholes surveyed in 1986 yielded between 20 and 45 l/s. In 1986 the yields of the boreholes used for irrigation ranged from 3 – 35 l/s (Jolly, 1986). Recharge to the aquifer has been estimated at between 2 and 5% of annual rainfall. A simple rainfall model (DWAF, 1990) is used to estimate recharge as:

$$R = 0.08(MAP - 342)$$

Equation 1

where R is recharge (millimeters), MAP is mean annual precipitation, and 342 is the minimum annual rainfall (millimeters) required for recharge to occur in the basin. This relationship assumes that uniform recharge occurs over the entire basin, and that there is no temporal variation during each season.

Groundwater use

While some water from the aquifer is used for livestock watering and domestic supply, the main water use is irrigation. There are more than two hundred farms in the area, of which 50 have irrigation activities. The remainder of the farms utilise groundwater for livestock watering. The main crops that are irrigated include potatoes, wheat, maize, cotton, oats, pumpkins, and vegetables (tomatoes, onions, etc). Of the 335 boreholes surveyed in the area in 1986, 69 % were used for irrigation, 27 % for domestic purposes, and 4 % for livestock watering (Jolly, 1986). In terms of volume, irrigation accounted for 95 % of all abstractions (Jolly, 1986). Currently the largest irrigated area is under Irish potato, followed by maize.

Data sources and analysis

During the first phase of the study the data considered were obtained from various sources. In the past most of the farmers did not measure abstraction. Abstraction data were estimated from calibration of sprinkler (center pivots) discharge using electricity consumption records obtained from Eskom, the electricity supply authority (Bertram, 2001). Some of the abstractions were based on calculated crop water requirements and irrigated areas obtained from farmers records of cropping calendars. The abstraction figures given in this paper were consolidated from the various independent studies that have been carried out in the area. Estimated groundwater abstraction, irrigated area, and depth to groundwater are given in Table 1.

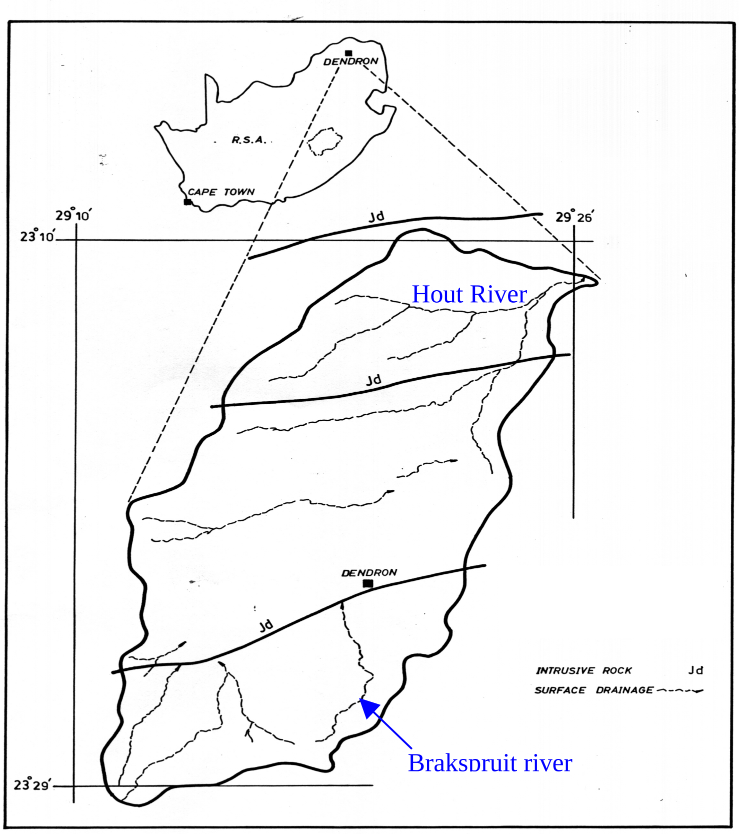

Figure 1: Location of study area

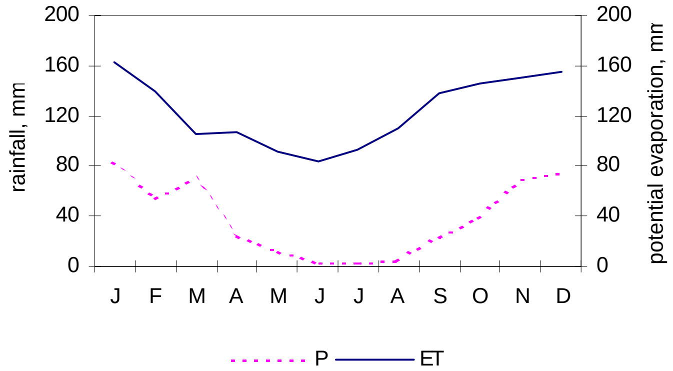

Figure 2: Longterm average rainfall and potential evaporation.

The recharge figures used are estimates obtained by the DWAF previously using the rainfall model relating rainfall to recharge (equation 1). Using this model it is assumed that no recharge occurs when annual rainfall is less than 342 mm. Recharge during three different periods (1969 – 70; 1970 – 71; 1984 – 85; and 1999 – 2000) estimated using the DWAF model is given in Table 2. Following this model and using annual rainfall data, there are several years when no recharge occurred (Figure 4).

Year of study	Area irrigated (ha)	Estimated abstraction 10^6 m^3	Depth to groundwater (m)
1968	1319	9.3	12 – 21
1974	1474	8.5	15 – 35
1986	3579	21.0	40 – 50
2000	__	__	50 – 100

Table 1. Abstraction and irrigated area trends in the Dendron area.

Period	Recharge as % of rainfall
1969 – 1970	5.5
1970 – 1971	4.3
1984 – 1985	3.0
1999 – 2000	< 2

Table 2. Estimated recharge (based on the DWAF model) to the Dendron aquifer as a percentage of rainfall (Source of rainfall data: The Agricultural Research Council's Institute of Soil Climate and Water).

Crop water use and irrigation water management

The water use by crops per unit area is highly variable. For some crops, water use ranges from about 3 000 to over 10 000 m^3/ha per season (Jolly, 1986). One of the main reasons for this large variation is poor quality water in some areas. In such cases more water that actual crop requirement is applied to mitigate the potential harmful effects of poor quality water. The variability in water requirements during the season is also observed between different crops. Some of the available abstraction data (Jolly, 1986) reflect the different abstraction levels for different crops. The largest water user in the area has traditionally been maize. Abstraction levels, representing crop water requirements, for seven crops normally grown in the area are shown in Figure 4. Potatoes, the more commonly grown crop currently, have crop water requirements about three quarters that of maize. Cropping patterns have changed over the years, with most farmers having switched from growing maize to potatoes, vegetables, and other crops with lower water requirements. Although this shift in cropping patterns may have been directly price-driven (the maize price is lower than that of all the other crops), it has the potential to directly impact production costs if the cost of pumping is included. For example the shift from maize to potatoes results in a potential saving of over 2,000 m^3 of water per hectare per season in pumping costs.

Irrigation water management has changed over time, with a shift from furrow irrigation, to manual move sprinkler systems, and eventually center pivots that are currently used at most farms. Even with the center pivot irrigation systems some farmers have also made a shift from high to low pressure systems in order to save water (Cotzee, 2001). With the use of on-farm mini weather stations to compute evapotranspiration and crop water requirements more accurately, some of the farmers in the area now follow accurate irrigation scheduling. At some farms (e.g. Cotzee) tensiometers are used for mapping out soil moisture profiles for scheduling timing of irrigation. All these measures target reduction of irrigation water requirements, and abstraction rates.

A DWAF study to establish the area that could be irrigated with aquifer resources showed that only 3 % of total farm area could be irrigated without over-exploiting the aquifer. The farmers' union has agreed to use the 3 % rule which stipulates that for every 1 000 hectares, only 30 can be irrigated (Cotzee, 2001).

Recovery of groundwater levels is said to have begun sometime between 1990 and 1991 (Bertram, 2001). However, farmers have not kept track of how much water they have saved due to the measures taken to counter the over-abstraction. The perceived decrease in depth to groundwater is not apparent from the data available. As there were no continuous monthly or annual groundwater level measurements, the data available is only representative of specific periods. Figure 5 shows the average depth to water table and borehole depth in 1969, 1974, and 1986 over the whole aquifer. In Figure 6 the depth to water table at two farms where water levels were measured regularly is shown. The rates of decline of the water table for these farms are given in Table 3. The depth to water table has continuously decreased, and the rate of decline has been increasing over time. The average borehole depth has increased over time. In 2000 the depth to water table ranged from 50 to over 100 m. Despite the awareness on over-abstraction, the changes in cropping patterns and irrigation scheduling, and other measures taken to reduce abstraction, the depth to the water table has continued to increase, with the rate of increase from the mid-eighties to the nineties greater than of the preceding period.

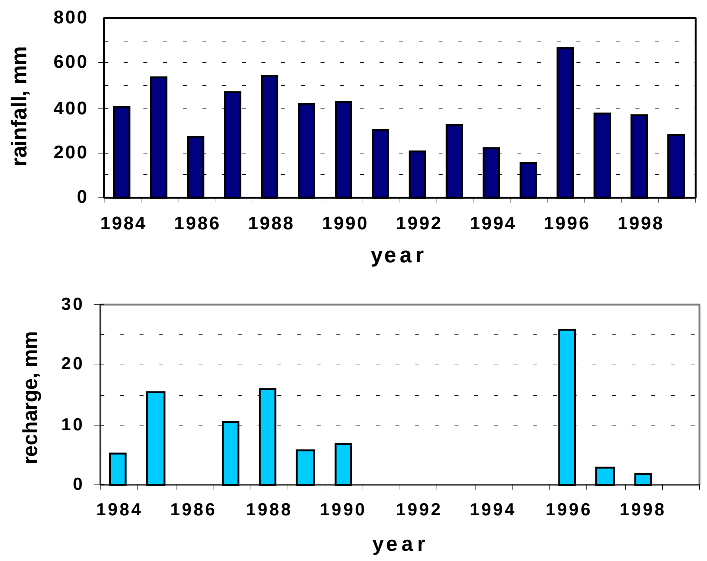

Figure 3. Longterm rainfall and estimated recharge in the Dendron area.

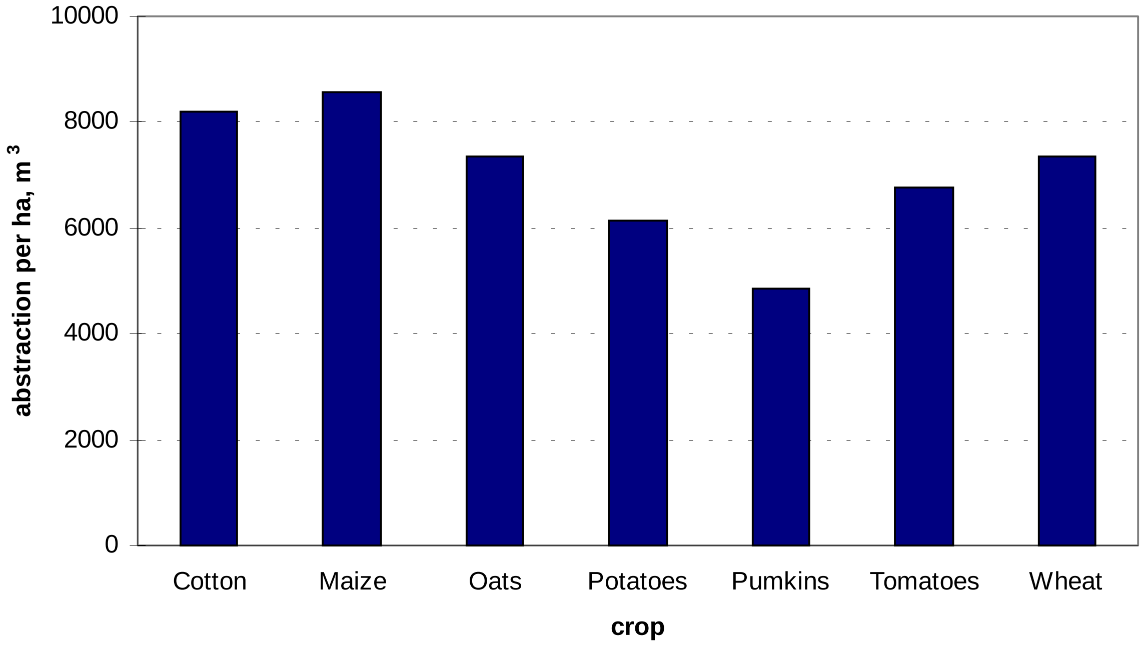

Figure 4. Groundwater abstraction per hectare for the different crops grown in the area.

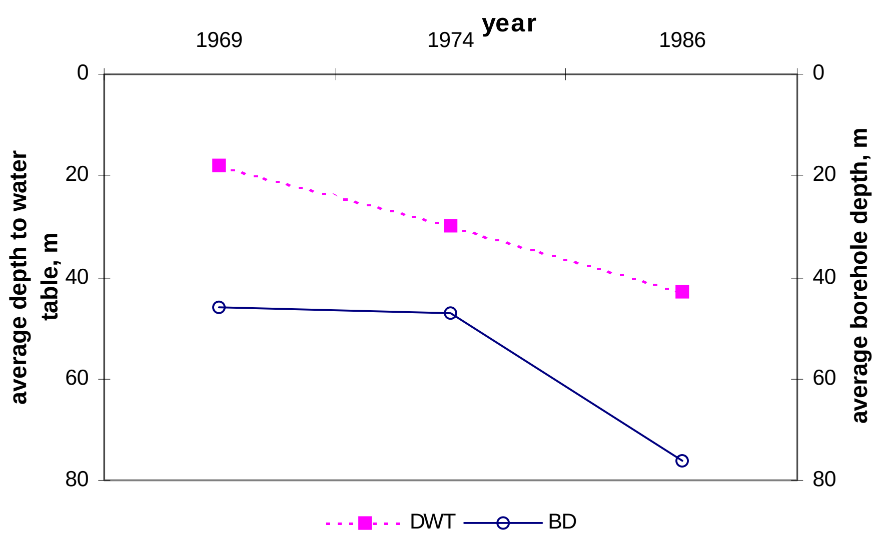

Figure 5. Average depth to water table (DWT) and average borehole depth (DB) (Source: Jolly, 1986).

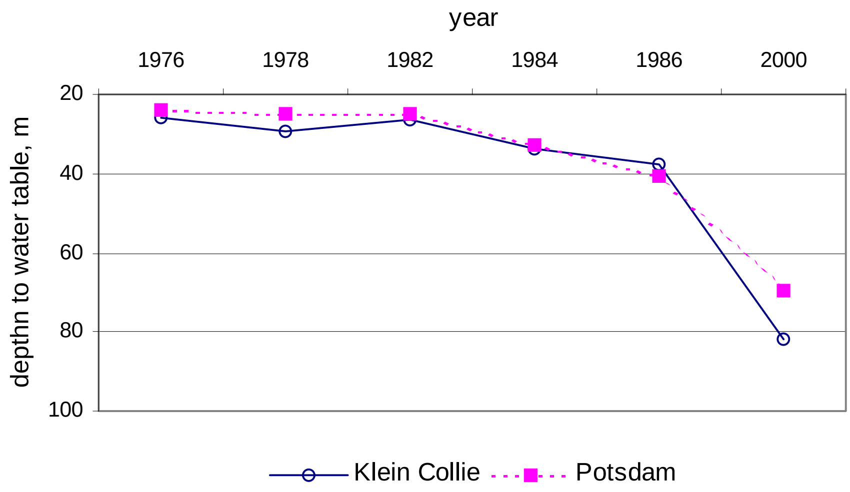

Figure 6. Changes in depth to water table (1976 – 2000) at Klein Collie, and Potsdam farms (Source: Jolly, 1986 and DWAF 2001, unpublished data).

Period	Rate of groundwater level decline, m/year	
	Klein Collie	Potsdam
1976 – 1982	0.14	0.28
1982 – 1984	1.79	2.00
1984 – 1986	1.04	1.97
1986 – 2000	3.16	7.24

Table 3. Rate of decline of groundwater levels

DISCUSSION

There are no reliable surface water sources in the catchment, making groundwater the only water source. As a result spontaneous drilling of boreholes is inevitable. When a high-yielding borehole is sunk, other boreholes quickly mushroom around it, resulting in boreholes being sunk too close to each other such that pumping in one influences others around it.

The declining groundwater levels could have been caused by over-abstraction when centre-pivots were introduced. The same can be said of the switch from diesel to electric pumps. Operations became easier and more land could be irrigated. Also pumps could be run over longer periods. Unless a deliberate decision to limit irrigated area is made, it is likely that farmers, inspired by possible increased returns, will irrigate more land and subsequently abstract more water. Introducing new technology options without adequate support information are best introduced together with

Changing cropping patterns does not seem to have caused a reduction in the rate of decline of groundwater levels. With data from a few observation boreholes, it is apparent that groundwater levels in the aquifer have continued to decline despite all the awareness created. Although not conclusive at this stage, awareness creation on its own does not seem to be an effective tool in groundwater management. In the case of the Dendron aquifer, other means of controlling abstraction levels and thus managing the groundwater are necessary. Water table has kept falling because the changes in demand haven't fed back into daily water management systems. With a continuous information feedback system, mitigative measures might be put in place.

Over-exploitation of groundwater resources where there are no other resources may lead to the introduction of drastic measures such as limitations to cropped or irrigated area. This has potential negative impacts on farmers' income. More realistic limitations of irrigated area may be required in Dendron to redress over-exploitation and mitigate drastic measures such as irrigated area reduction.

More explicit abstraction rules are required. The 3 % rule that was agreed to by the farmers' union does not seem to have curbed continued decline of water levels in the aquifer. Water use is primarily linked to the crop more than to the area, thus restricting irrigated area to only 3 % of total farm area may not necessarily reduce abstractions. A system is required that will inform users on how much water they can abstract in one season. It is recommended that the aquifer is modeled more realistically, taking into account that the recharge process is not uniform across the mainly fractured aquifer. Relating water levels in key observation boreholes to aquifer storage levels would provide an indicator for the status of the aquifer. Before the cropping season, water levels in these boreholes should be used to calculate the total area that can be irrigated in that season, allowing users to plan cropping accordingly.

ACKNOWLEDGEMENTS

The authors would like to thank the Department of Water Affairs and Forestry for provision of some data, and the Institute of Soil Climate and Water for rainfall data. The water use and cropping information provided by farmers in the Dendron area is gratefully acknowledged.

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Water resources planning and management for sustainable development: the missing link

Jonathan I. MATONDO

Dept of Geography and Environmental Sciences, University of Swaziland, Swaziland

matondo@uniswacc.uniswa.sz

ABSTRACT

Air, land and water are the three fragile components of the Spaceship Earth. These three components are highly integrative resources and therefore, must be properly managed in order to ensure adequate public health, food supplies and transportation. The quality of life is directly dependent on how well these resources are planned and managed for sustainable development. The above three resources are highly integrated and thus the need for multipurpose water resources planning and management. Multipurpose water resources planning and management also emerged as a result of an increase in competing and conflicting water uses and due to rapid population growth and rising expectations of a better life.

This paper discusses the conventional and integrated water resources planning and management approaches for sustainable development. The author agues that, both approaches if implemented very well are geared to deliver the same end results 'sustainable development'. However the paper concludes that, both approaches have failed to deliver the end results due to the missing link. This missing link in both approaches is the institutional framework that coordinates water resources planning and management responsibilities and activities at all levels of government.

INTRODUCTION

The fragile components of Spaceship Earth are principally air, land and water. These three highly interactive resources must be properly managed in order to ensure adequate public health, food supplies and transportation. The quality of human life is directly dependent on how well these resources are managed. Water is the most important catalyst for human development. It is a major input in almost all sectors of the human endeavor. Ancient civilizations grew up in the river valleys of Tigris and Euphrates, the Nile, Indus, Hwang Ho etc. where there was plenty of water. During those days the planning and management of the water resources were for single uses. As time passed on it was recognized that resources were integrated and therefore, the need for longer-range planning that would include multi purpose systems resources. Multipurpose water resources planning also emerged as a result of an increase in the competing and conflicting water uses and due to rapid population growth and rising expectations of a better life.

The conventional water resources planning and management is from TOP BOTTOM approach coupled with public hearing in developed countries. While in developing countries it is the experts and the decision makers (usually the politicians) who have much say on the planning and implementation of water resources projects. The public has no much say but to accept what is being planned for them.

Integrated Water Resources Planning and Management (IWRPM) is participatory, technically and scientific informed and is taken at the lowest level, but within the framework at the catchment, basin and aquifer level which are the natural units by which nature manages water (World Commission on Water, 2000). Stakeholder participation is the key point in IWRPM approach. That is the empowered community has the responsibility to address local issues in a coordinated and integrated way.

The earlier water resource project plans did not take into consideration of the environment and thus had negative effects to the environment. The world society recently has put emphasis on the need in water resources planning and management for consideration of the quality and aesthetic integrity of the environment. The environmental impact assessment is now an integral part of a water resources plan. According to Loucks, (2000), 'Sustainable water resources systems are those designed and managed to fully contribute to the objectives of society, now and in the future, while maintaining their ecological, environmental and hydrological integrity'.

It has been established by scholars that water resources problems are going to be more complex in the future world wide (Simonovic, 2000; Wurbs, 2000; and Singh 1995). Population growth, climate variability, regulatory requirements, project planning horizons, temporal and spatial scales, socio and environmental considerations, trans boundary considerations etc all of these contribute to the complexity of water resources planning and management problems (see figure 1). Systems analysis has been established as one of the tools for solving complex water resource problems. (Dantzing, 1963; Hillier and Lieberman, 1990; Loucks et al 1981). According to Simonovic (2000), Complex water resources planning problems heavily rely on systems thinking, which is defined as the ability to generate understanding through engaging in the mental model - based processes of construction, comparison and resolution through the use of computer software tools such as STELLA, DYNAMO, VENSIM, POWERSIM (High Performance Systems, 1992; Lyneis et.al, 1994; Ventina, 1996; Powersium Corp., 1996).

This paper presents a discussion on the Conventional and Integrated Water Resources Planning and Management approaches. The application of systems analysis in water resources planning and management is also presented. The missing link in both approaches of water resources planning and management will be discussed.

CONVENTIONAL WATER RESOURCES PLANNING AND MANAGEMENT

Planning is involved in virtually all human endeavours. Water resources planning as defined by the USA National Water Commission (1966) "is the creative and analytical process of (a) hypothesizing sets of possible goals, (b) assembling needed information to develop and systematically analyze alternative courses of actions for attainment of such goals, (c) displaying the information and the consequences of alternative actions in an authoritative manner (d) devising detailed procedures for carrying out the actions, and (e) recommending courses of action as an aid to the decision - makers in deciding what set of goals and courses of action to pursue".

A goal is a desirable state of affairs where a person or an integrated group of persons is actively striving to achieve. The first step in water resources planning is that of analyzing the possible sets of goals which the community or country is striving to achieve for the benefits of its citizens and the environment. The general goal in water resources planning is the improvement of human welfare. A lot of data is required in the planning of water resource projects (hydrological, economic, social economic, demographic, physical, meteorological, etc). All the above

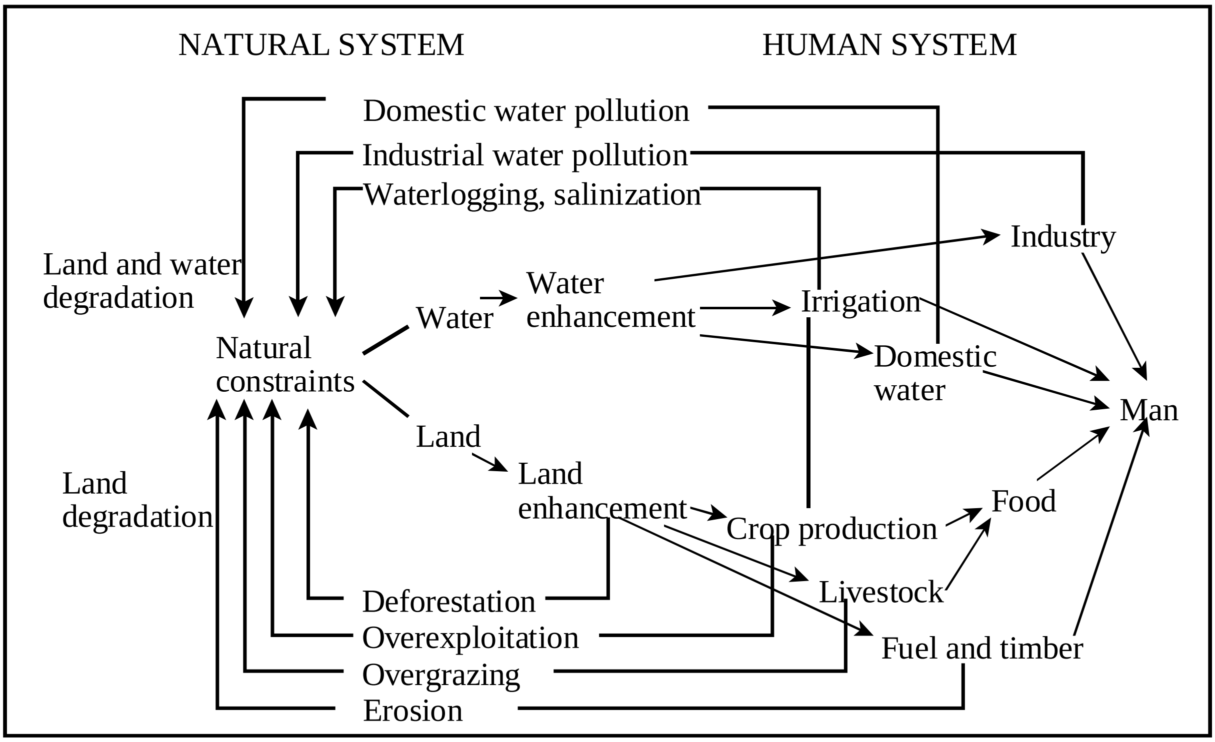

Figure 1. Complex interactions and feedbacks between the natural and human systems (Faleknmark, 1986)

information is required for the analysis of alternative plans. The major objectives in water resources planning are: national economic development, regional development, environmental quality and social well-being. Therefore, each alternative plan should display the beneficial and adverse effects on all the four major objectives. The definition also emphasizes that each alternative plan should have detailed procedures for carrying out the actions. A plan should also have the recommendations on the possible courses of actions to pursue. This is intended to help the decision markers to make the right decision. We should also bare in mind that engineers, water resource planners etc are not the decision makers. This responsibility rests in the hands of decision makers who are the politicians. Therefore, the politicians must be fed with the right information.

The total planning process involves goals, objectives, activities, and resources of all kinds that can seldom be considered independently. Meeting the needs of the people requires consideration of land use, water, housing, transportation, education, and many other sectors of human endeavors. The general interrelated hierarchies in the planning process can be described by the following classifications of planning activities.

Table 1: Classifications of water resources planning activities

Planning Jurisdiction	Scope of planning programs	Stages of planning	Planning Area
International National/Ministerial Regional, District Village level/local	Multi sectoral Sectoral Functional	Policy planning Framework planning General appraisal planning Implementation planning	Urban Basin

Planning jurisdictions

The planning, development and management of water resources can be carried out at international level. This is especially the case when a watercourse crosses several national boundaries, such as the Zambezi river, Nile river etc. Planning for water resources can also be carried out at national, regional, District and at village level.

Scope of planning programs:

The scope of planning programmes as indicated above are: Multi-sectoral, sectoral and functional. Multi-sectoral planning is the coordinated planning for all sectors of the public endeavor, such as land use, housing, education, water resources, energy supply etc. Sectoral planning is the integrated planning for all functions within one sector, such as water resources. While, functional planning is the planning to meet a specific need within one sector such as flood control, hydropower etc.

Stages of Planning

The stages of planning as indicated in Table 1, are: Policy, framework, general appraisal and implementation planning. Policy planning is the overall goals and program objectives, policy development, overall budget and priority analysis, dissemination of program guides etc. Framework or reconnaissance planning is the identification of general problems and needs, outlining a range of possible alternative futures, inventory of available resources and general opportunities, assessment of overall adequacy of resources, and determination for further investigation. General appraisal planning is the broad evaluation of alternative measures for meeting hypothesized goals and objectives, with recommendations for action plans and programs by specific entities. Implementation planning is the investigations of a specific structural or non structural measure, or a system of measures, in sufficient detail to determine whether it will meet established goals, objectives, and criteria and if so, that it is physically possible of implementation within the estimated costs and within limits of financial feasibility.

The Need for Multi - Sectoral Planning

The USA National Commission on Water (1966) explains the need for multi-sectoral planning as follows: The increasing complexity of regional economies and the increasing degree of interrelationships between segments of society virtually require that plans for the water resources sector be consistent with and complementary to plans being developed for other sectors of the human endeavor.

Multi-sectoral planning is essential if:
(a) Sectoral plans, such as water resource management plans, are to be properly related to planning in other sectors such as agricultural; (b) The various sectoral plans are to be properly related to existing and proposed land-use development; and (c) All sectoral plans are to be related to basic societal development goals and objectives. Such multi-sectoral planning can avoid costly inconsistencies and conflicts; assure consideration of the true benefits and costs of alternative plan proposals - - including social costs to be determined; and help identify otherwise unforeseen secondary and tertiary effects of plan proposals.

The interrelationships and sequence of multi-sectoral, sectoral and functional planning are significant. Properly performed, multi-sectoral planning should precede sectoral planning and sectoral planning should precede functional planning.

The probable complexities and interrelationships of the future such as the potential for competition between irrigation and municipal water supply and the opportunities for recycling of wastewater for reuse as water supply emphasize the importance - - the virtual necessity - - that functional planning be consistent with plans for other functions in the water sector. Therefore, all phases of sectoral planning should fit together to conform to a multi-sectoral plan and that all phases of functional planning fit together to conform to a sectoral plan.

It has been mentioned that water is involved in most all sectors for the human endeavor. Water resources planning and management decisions can have environmental, physical, social, and economic impacts that are widespread and pervasive. It can be seen from the above that, water resources planning and management involves many disciplines such as: engineering, economics, social science etc. Therefore, water resources planning and management is carried out by a team effort (multi-disciplinary). Solutions to complex water resources planning and management problems requires the use of systems analysis

APPLICATION OF SYSTEMS ANALYSIS

It has already been mentioned that, water sources problems are complex in nature. Systems analysis has been established as a suitable tool for solving water resource problems. Systems analysis is defined as: a rational approach to arriving at management decisions for a particular system, based on the systematic and efficient organization and analysis of relevant information. There are a number of terms which are used synonymously with systems approach, and these include: systems engineering, operations research, operations analysis, management science; cybernetics and policy analysis. Hall and Dracup (1970) define Systems Engineering as the art and science of selecting from a large number of feasible alternatives, involving substantial engineering content, that particular set of actions which will accomplish the overall objectives of the decisions markers, within the constraints of law, morality, economics, resources, political and social pressures, and laws governing the physical, life and other natural sciences.

During the planning stages, the issues here is to find the optimal firm water (W), firm power (P) and flood reserves that will meet the water and power demand and offer flood control reserves while maximizing the overall benefits. This is what is often referred to as the pre-contract studies problem. The optimization problem of the pre-contract studies is expressed as follows:

$$MAXIMIZE \quad b_w.W + b_p.P + \sum_{t=1}^{12} b_f V_{flood,t}$$

$$SUBJECT \quad TO$$

$$V_{t+1} \quad = V_t + I_t + R_t + L_t - E_t - Q_t - N_t$$

$$Where$$

$$Q_t \quad = a_t.W + q_t, \qquad q_t \geq 0$$

$$E_t \quad = e_t.A\left(\frac{V_t}{2} + \frac{V_{t+1}}{2}\right)$$

$$P_t \quad = K.Q_t.h\left(\frac{V_t}{2} + \frac{V_{t+1}}{2}\right).\Delta t$$

$$P_t \quad = P_t.P + \bar{P}_t \geq 0$$

$$V_{\min} \leq V_t \leq V_{\max} V_{spill}$$

$$Q_{\min} \leq Q_t \leq Q_{\max}$$

$$P_{\min} \leq P_t \leq P_{\max}$$

$$V_{flood,t} = V_{spill} - V_{\max}$$

The above problem can be solved using any optimization technique (Linear programming etc). The solution to the above will yield the optimal values of firm water W* and firm power (P*), as well as the optimal value of V_{max} for each month t. It should be pointed out here that the releases to the natural channel are specified a priori. The releases to the natural channel are required to meet the in stream water requirement, the water requirement for the sustainability of the riverine environment and the minimum water quality abatement. If a river crosses international boundaries, the N_t will also include the amount of water left for the downstream riparian state in addition to the above requirements.

The obtained firm water and power is useful information for engaging in contract negotiations with water and power users. The reservoir(s) has to be operated in really time in order to minimize contract violations at the same time maximize beneficial use of the reservoir(s). This is what is referred to as the post contract or real-time operational problem.

The optimization problem for post contract studies is expressed as follows:

$$
\begin{array}{ll}
MINIMIZE \sum_{t=1}^{T} \left(a_t.W^* - Q_t \right)^2 if & Q_t \leq a_t.W^* \\
\qquad 0 \qquad if & Q_t \geq a_t.W^* \; \Big) \mu_t \\
\quad + \Big(\big(b_t.P^* - P_t \; \big) if & P_t \leq b_t.P^* \\
\quad 0 \qquad\quad if & P_t \geq b_t.P^* \; \Big) \gamma_t \;\; \Big)
\end{array}
$$

Where μ_t and □$_t$ are appropriate weighting factors to establish operational priorities and a_t is a firm water distribution coefficient which, is expressed as follows:

$$a_t \quad = \frac{D_t}{\sum_{t=1}^{12} D_t}$$

Where D_t is the total water use for all the sectors in month t. The real-time operational problem is solved for periods of less than a month. The constraints are essentially the same as for pre-contract studies, except that they are defined over short time intervals. Forecasted stream flows are used in the real-time operational problem instead of the historical record or critical low flow period. Water resources management is here ia basically an attempt to decide on how water should be allocated among the various conflicting and competitive uses without compromising the quality of the environment.

What can be summarized here is that, the conventional water resources planning is integrated in the sense that plans must fit into a multi-sectional plan. The plans are driven by the four major objectives namely: national economic development; regional development; social well being and environmental quality. The preservation of the natural environment is embedded in the environmental quality objective which is also preserved in the optimization problem for pre-contract and post contract studies. The requirement for an environmental impact assessment for each plan emphasizes environmental protection. Therefore, water resources planning if conventionally done well will lead to sustainable water resources development. However, it has been established that conventional water resources planning has failed to lead to sustainable water resources development (Falkenmark 1993, SCOWAR 1998). This has been the case especially in developing countries where environmental preservation has received less attention to communities who have to deal with the immediate realities of poverty. However, the major missing link to the success of conventional water resources planning for sustainable development is explained in the following sections.

Integrated water resources planning and management has come about as a solution to the failure of the conventional water resources planning to produce sustainable water resources development, especially in developing countries.

INTEGRATED WATER RESOURCES PLANNING AND MANAGEMENT

It has been established that each body of water is a delicately balanced component of the landscape in a continuous interaction with the surrounding air and land. Therefore, water is intimately related to all mans' activities in the landscape and whatever occurs in the land and in the air also affects water

(Kindler, 19912). IWRPM has also emerged from the perception water as an integral part of the ecosystem, a natural resource, and a social and economic good (United Nations, 1992a).

Many authors in the literature are concerned with integrated water resources planning and management (Duda et al 2000; DWAF and WRC 1998; Land et al 1980; Grigg, 1996 etc) while others are concerned with integrated catchment management (Hu 1999; Frago 1998; Heathcote, 1998; DWAF 1998; Mitchell et al 1993 etc). The definition of integrated water resources planning and management is the incorporation of the socio human factors, the economic issues and the ecological system. Which means that the society will continue to benefit from the utilization of the water resource while maintaining the environment and the resource base to meet the needs of the future generations. Integrated according to Downs, Gregory and Brookes (1991) means that more than one sectoral interests are linked at both the operational and strategic levels. Integrated catchment sets out to integrate, in a systems approach, all environmental, economic, and social issues, within the bounds of a river basin, into an overall management philosophy, process and plan (product). This is aimed at delivering the optimum possible mix of sustainable benefits for future generations and the communities in the area of concern, whilst protecting the natural resources which are used by the communities and minimizing possible adverse social economic and environmental consequences (DWAF, 1997).

The above definitions on IWRM and ICM seem to be talking of the same thing. Therefore, I have tended to go along with integrated water resources planning and management and leave the catchment as the planning and management unit.

I have always tended to believe that, we should start from the planning level and then move to the management level. This is because if you have not planned, you may have nothing to manage (could be true or false). Therefore, integrated water resources planning is a process whereby the water utility determines the options that at least cost will provide its customers with the water related services that they demand rather than the water itself while maintaining the integrity of the environment (Howe 1999). Integration here has the same meaning as in the conventional water resources planning. That is, all the sectors of the human endeavor, including land use and the environmental are taken into consideration. Integration is then seen here as the art and science of blending all the items above into a whole.

Water resources management is defined as the utilization of, existing and/or planned facilities and institutions in the most beneficial way through appropriate rules, policies and procedures to achieve greatest benefits through legal authority. At the private level, water resources management effectiveness is directly measured by the profits accruing while at the government level is measured by the achievements in the national economic development, environmental quality, regional development and social well being. The private sector is geared at the maximization of benefits from the utilization of the water resources. Therefore, without proper legislation and policies, environmental degradation is likely to take place if the management of the water resource is entrusted in the private sector. An example is the utilization of the Colorado River which leaves only a trickle of water to reach the Colorado delta, thus causing environmental and social degradation.
Integrated water resources management plan has to take into consideration all the sectors of the human endeavor, land use and the environment. The benefits of integrating the various aspects of water resources management have been identified by many researchers, policy makers and water managers (Grigg 1996).

According to Malano (2000) there are four major principles in integrated water resources planning and management and these are:

- Sectoral (and sub-sectoral) integration that takes into account competition and conflicts among various users.
- Geographical integration.
- Economic, social and environmental integration that take into account of social, and environmental costs and benefits and
- Administrative integration that coordinates water resources planning and management responsibilities and activities at all levels of government.

The Global Water Partnership IWRM Toolbox has policy guidance and operational tools. The operational tools comprise of the enabling environment, institutions and management instruments (GWP, 2001).

Post and Lundin (1966) provides a full range of characteristics associated with IWRMS. Another activity which has been associated with IWRMS is stakeholder participation (Blackmore, 1995). It has been pointed out by several researchers (Ashton et al 1998, Savanije et al 1998, World Bank, 1995) that stakeholders should be informed about the planning, development and management of the water resource. Stakeholder participation under the conventional water resources planning especially in developed countries the USA in particular has been through public hearings. However, stakeholder participation through public hearings has not been possible in developing countries and this has led to the failure of many water schemes. Community empowerment has been established to generate some sense of responsibility and thus sustainable development and management of water supply schemes.

All the factors and interactions in conventional and integrated water resources planning and management have been presented. I have always though that integrated is a catchword while multi-sectoral is the principle approach in the conventional water resources planning and management. Therefore integrated and multi-sectoral approaches have a lot in common and few

differences, if any and if each is performed properly will yield the same results.

However the conventional and integrated water resources planning and management approaches have failed to accomplish a sustainable water resources development and management. There is a vital link that is missing in both approaches which, is hindering or has hampered the sustainable utilization of the water resource in both developed and developing countries. Institutional framework is the missing link and is presented in the following section.

INSTITUTIONAL FRAMEWORK : THE MISSING LINK

It has been pointed out that conventional water resources planning is usually isolated from land use planning, concentrating on water resources alone (Falkenmark 1993; Scowar 1998). However, I do not agree with them because as explained earlier, multi-sectoral planning is indeed integrated water resources planning and management and it takes into consideration the land use issues and environmental conservation. Mitchell (1987) contends that "the process in adopting an integrated approach in the 1980s has been hesitant and unsystematic in part because of the absence of suitable models for implementation". However, at the turn of the millennium, I believe that we now have the modeling capability to tackle the complex problems in water resources planning and management (Wurbs 1998, Singh, 1995). Kuijpers (1993) believes that the gap between integration at a strategic level and at the operational level is still very large. He goes on to argue that IWRMS approach cannot be achieved and implemented in a fragmented institutional set up, which includes several largely autonomous and poor coordinated administrative bodies. To quote Duda et al 2000 “The failure to achieve integrated water resources management has been attributed to the strength of sectoral ministries in opposing the concept, as well as institutional bottlenecks occurring in implementation” . He goes on to state that the availability of funding to “fix” problems caused by fragmentation and inter organizational rivalries keeps conflicts at bay. According to Mosley (1998) the core hindrance to integrated information management and thus water resources planning and management is the involvement of several often uncoordinated organizations in the water sector. This is true in most developing countries. In the South African situation and therefore in most developing countries, the lack of human resources, rugged individualism with the spirit of pioneering and protectionism through data pricing by the state and parastatals are crucial barriers to the coordination of water resources planning and management activities (Maaren and Dent 1995).

Therefore, the need for the creation of an institutional framework that will coordinate water resources planning and management responsibilities and activities at all levels of government is imperative for the success of conventional and IWRPM. The challenges of integrated land, water and ecosystem management on a basin scale can only be met by management at the lowest possible levels (Duda et al, 2000). To quote Duda et al, “Interministerial collaboration at the national level in terms of a standing inter-ministerial committee for integrated management represents the first step forward. There must also be created the sub-national, basin-specific inter-ministerial committees to ensure that sectoral ministeries collaborate among sub-national political jurisdictions for basin wide water resources planning and management”.

SUMMARY AND CONCLUSIONS

Conventional and Integrated Water Resources Planning and management approaches have been presented. Multisectoral is the principle approach in the conventional water resources planning and management. Integrated Water Resources Planning and Management is the incorporation of the socio human factors (stakeholder participation), economic issues and the ecological system. Therefore, it has been established that, if both approaches are well implemented in theory could attain same results.

However, conventional water resources planning and management has failed to lead to sustainable water resources development especially in developing countries where environmental preservation has received lees attention to communities who have to deal with the immediate realities of poverty. Stakeholder participation is the key factor in IWRPM is also not possible in conventional WRPM in developing countries.

Both approaches have failed to accomplish sustainable water resources development. The major factors that have led to the failure of both approaches are: fragmented institutional set up, institutional bottlenecks occurring in implementation, lack of human resources, sectoral ministries opposing the concept, poor coordinated administrative bodies and/or organizations in the water sector etc. The major missing link in both approaches is administrative integration (institutional framework), that coordinates water resources planning and management responsibilities and activities at all levels of government. This missing link has also been recognized by Global Water Partnership and has been included in the GWP IWRM Toolbox and in the Murray-Darling and Mekong river basin systems (Malano et al. 1999). The establishment of an institutional framework which, will coordinate all activities, is very vital for the success of Conventional and/or Integrated Water Resources Planning and Management.

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Selection of Flood Frequency Model in Tanzania using L-moments and the Region of Influence Approach

Gerald MUHARA

Kenya Meteorological Department, P.O.Box 30259,
Nairobi

Muhara@lion.meteo.go.ke

ABSTRACT

This study aims at establishing the underlying statistical distributions for various sites, derive hydrologically homogenous regions in Tanzania and establish the regional statistical distributions, based on the L-Moments diagrams. The parameters of these distributions are estimated. Linear regression models for various regions and eventually the whole country are also established.

The region of influence (ROI) method of defining hydrologically homogenous regions has been used in this study. The method gives satisfactory results but only after coupling it with a statistical tool for checking regional homogeneity. The regions derived using this method compares well with those defined earlier using the method of Principal Component Analysis (PCA).

Of the Twelve regions in Tanzania 2 were described by Log Logistics (LLG), 1 by Generalized Pareto (GPA), 4 by 3 Parameter Lognormal (LN3), and 3 by Pearson type three (P3). One region did not have sufficient data for analysis.
The study revealed that, instantaneous annual maximum flood in Tanzania can be estimated by P3. Regional parameters of P3 for standardized instantaneous annual maximum flow data in Tanzania are: QMEAN=1.00, QSTDV=0.58 and QSKEW=1.51

The linear regression model for the country takes the form: Log Q(bar)=0.58 Log A + 0.88 Log R + 0.14 Log S + Log C
with R squared = 0.48 and standard error of Q(bar) estimate = 0.42 and Log C=-2.84. Thus the model is a poor estimator of Q(bar), however regional multiple linear regression models show high efficiency.

Keywords: *L-moments; PWM; regionalization; homogeneity; heterogeneity; regression; quantiles*

Is the Pungwe Water Supply Project a solution to water accessibility and sanitation problems for the households of Sakubva, Zimbabwe?[1]

Azwidowi MUKHELI[2], Gilbert MOSUPYE, and Larry A. SWATUK

School of Government, University of the Western Cape, Private Bag X17, Bellville, 7535

[2] amukheli@hotmail.com

ABSTRACT

Following the severe drought of 1991/92, the city of Mutare embarked on a multi-million dollar water supply project. This project brought water from the Pungwe River via pipeline to the city of Mutare. This project was deemed to be a satisfactory solution to the water and sanitation problems in Zimbabwe's so-called 'third city'. For residents of Sakubva township, the Pungwe project has ensured a clean water supply. However, it has made very little impact in terms of accessibility to water and sanitation facilities to those same residents. City Council's and Government's reluctance to deal effectively with these issues compromises the concept of water demand management as encompassed in the Zimbabwe National Water Act of 1998. Moreover, the combination of overcrowding in Sakubva and the highly mobile nature of its 'resident' population has negatively impacted on planning, provision and management of water and sanitation services. In this paper, the authors examine these and related issues in detail. The paper concludes by looking at different water and waste management strategies that may be employed in Sakubva. Moreover, the authors believe that lessons from and suggestions for Sakubva may be extended to other high-density areas throughout the Southern African region, so offering region-wide policy recommendations.

Keywords: *Pungwe water supply project; water accessibility; Sakubva; communal ablution block; water demand management; sanitation; waste management*

1. INTRODUCTION

Sakubva is a low-income, high density suburb of Mutare located approximately five kilometres south of the city. The area is 12.9 km square and is divided into various sections: Mazhambe, NHB, Muchena, Mundembe, MacGregors, OTS(Old township), Chisamba Singles, Old Chisamba, Devonshire, New Dangare, Old Dangare, New Zororo and Old Zororo. With the exception of New Dangare, Devonshire and New Zororo which have private water and sanitation facilities, the rest of the sections use communal ablution blocks for their water and ablution purposes. Sakubva township is the first residential area to be built in the city around 1910. Originally, it was designed to house 5000 people. Today, the population of Sakubva is estimated at 50,000 (Tagwira and others, 2000: 4). Sakubva has benefited in the establishment of the Pungwe Water Supply Project. The severe water scarcity/shortages that hit Mutare and the whole country in general after the 1991/2 drought was counteracted by the establishment of this multi-million dollar project, which has ensured clean water supply to the city of Mutare (http://www.ngw.nl/int/afr/mutare.htm). Since the establishment of this

[1] The authors would like to acknowledge the assistance of the following in the completion of this study: the Water Research Commission of South Africa for generous scholarship support; Sakubva Peer Educators Silas Ziwono and Sydney Mangweka and their families; and all those in Harare, Mutare and Sakubva who helped along the way.

project, Sakubva does not have water shortage problems per se, rather the problems are related to management of this resource and related sanitation/waste services.

2. POPULATION GROWTH AND ACCESS TO WATER

The population of Sakubva is increasing at an alarming rate due to both in-migration and natural increase. This situation puts more pressure on already inadequate water and sanitation facilities. Sakubva was originally established for migrant workers who provided cheap labour in the white-owned industries of that time. Therefore, the Sakubva of today is a legacy of colonialism.

Different strategies have been devised to decongest Sakubva (Muskwe, 2001). For example, Hobhouse, Dangamvura, and Chikanga suburbs were established. This only worked for a short period of time as it, in effect, simply created space in Sakubva for more people from rural areas and neighbouring countries. The uncontrollable and unknown population of Sakubva has made planning and implementation difficult on the part of the City Council of Mutare. Landlords/landladies in Sakubva have contributed to overcrowding by renting shacks. According to Tagwira et al (2000: 7), an average of 14-16 people per stand were to be found in Chisamba. Whereas the township has 6225 legal housing structures, many properties also contain four or more shacks. In 1995/6, the City Council of Mutare considered demolition of shacks as part of the solution. As Muskwe (2001) points out, the Minister of Local Government gave the Council a go-ahead and it was only after demolition of 50 shacks that they were stopped.

Sakubva township has various kinds of households and forms of home-ownership – some with piped water and in-house toilets, but many more dependent on communal ablution blocks *(bava*) and open-access standpipes. For residents with home-ownership, access to water and sanitation facilities is better, since most of these people can afford to pay for services. Residents with home-ownership have a sense of responsibility to resources. Most houses in these sections were constructed after 1990.

3. COMMUNAL ABLUTION BLOCKS AND THEIR CONSEQUENCES

Most residents of Sakubva are without home-ownership (Muchena, Mundembe, MacGregors, Mazhambe, OTS, NHB, Chisamba Singles and old Chisamba). In these sections, water taps have become “ever-flowing fountains” gushing with water that can become home to disease-carrying organisms. Water from these communal blocks flows through main drainage systems that are inadequate and plugged. This plugging is mainly due to waste that accumulates in these drainage systems as they are not cleaned regularly. This often results in overflow which ends in pools of stagnant water or streams which flow directly to Sakubva River. This was a common sight in Old Townships (OTS) section. Water drainage systems also become plugged due to the simple fact of numbers: too many people overstress the system. Additionally, toilets become plugged because most people use newspaper instead of toilet paper. Small children can be seen each morning carrying “night soil” wrapped in newspaper for disposal at the common blocks. On its way to Sakubva River, some overflow is harnessed for agricultural purposes -- a good use of otherwise wasted waters. As early as six o’clock in the morning, women can be seen queuing up waiting for their turn to do their washing in a ‘bay’ accommodating three people using one tap that is always running. The first one to come will stand next to the mouth of the tap and the other two will use the water that is first used by or flows past her. The communal block is a very animated area with many women of varying ages and many small children about. During the colonial era each communal block in Sakubva was meant for 8 males. Typically today, each ablution block is divided into two sides: one for men and one for women. The toilet is a hole in the cinder block floor. Above this ‘toilet’ is a pipe that serves as a ‘shower’. There is also a separate room for showering, usually with two water outlets. In no case did we find an ablution facility that did not have ever-running water. Today, these facilities must cater for 50-100 people (interview, Chirawu and participant observation). It is common practice in the township for people living in one section to ‘search out’ ablution blocks that are relatively clean but which may be in another section. Local people feel that this practice contributes to ‘common pool’ resource problems. Queuing for a shower in these blocks is a way of life, with many people rising as early as 4 a.m. to use facilities before their condition ‘deteriorates’ throughout the day. It is interesting to note that people coming to fetch water for survival purposes, i.e. for drinking and food preparation, do not queue. They are given preference to water use. These people, in almost every case women, fetch water using all manner of container: from 2 liter plastic bottles to rather large buckets.

Safe drinking water and adequate sanitation are basic needs essential to health and development generally (Fair, 1995). In their absence people are prone to a number of illnesses/diseases. The communal blocks in Sakubva are a health hazard. For example, dysentery is commonly transmitted when hands with faecal contamination come in contact with stored water. This is not uncommon owing to the high number of young children in this area. Children can often be found playing in areas (e.g. near to the river banks) where human waste is openly visible. There are few recreational facilities in Sakubva, so children tend to gravitate to these open areas.

Differences in accessibility to water in Sakubva results in theft. Reconnection of water supplies illegally after being disconnected for non-payment of accounts in Sakubva is common. Although the penalties can be heavy, the chances of criminals being caught are slim as the community has developed an “I-do-not-care” attitude. They have no sense of ownership of resources, thus they rarely if ever report offences. The fact that Sakubva is also a ‘dormitory suburb’ for migrant labour also makes it very difficult to instill a sense of ‘responsibility’ and ‘best practice’ among ‘residents’. Moreover, leaseholders in many areas are rarely residents themselves. It is a common situation to find the leaseholder living in his/her rural area and simply earning money from the illegal ‘sub-letting’ of his/her property. The condition of communal ablution blocks is therefore of no concern to the leaseholders. Given that the City Council lacks capacity to effectively implement proactive demand management strategies, the only readily available option is to shut off water. This type of demand management-through-punishment only exacerbates the difficult relations that exist between residents and City Council.

4. POLITICAL INTERVENTION

In the process of ‘revisioning’ Sakubva, politics has played a central role. Although most socio-economic problems in Sakubva result from overcrowding, City Council finds itself in a difficult political position to deal effectively with these issues. Politicians in need of votes agitate *against* demolition of shacks. The Executive Mayor of Mutare, Lawrence Mudehwe, hails from New Dangare section of Sakubva. Until recently, he still resided there. With its high numbers, Sakubva is a vote base for political power in Mutare. How politicians approach Sakubva, then, can start or end political careers. Thus, politicians tend to cater for the short-term interests of Sakubva residents.

5. WATER SUPPLY MANAGEMENT

5.1 The City Council and the water management structures

The Zimbabwean Water Act presents all stakeholders within a Catchment area with a platform to get involved in the management of water resources. The new institutional structure includes Catchment and Sub-Catchment Councils, River boards and, it is anticipated, water point committees. It is at the Catchment Council level where relevant stakeholders take decisions on how water can be equally distributed and efficiently used. The City Council of Mutare is a stakeholder in the Save Catchment Council and the Odzi Sub-Catchment Council. However, their participation has been haphazard at best.

5.2 "Pungwe falls" in Sakubva

The Pungwe project is heralded by many as an answer to water resource vulnerability in Mutare. This is demonstrated by the slogan "Pungwe Project Saves Mutare" displayed on a large billboard outside the City Council buildings. It may however be more accurate to say "Pungwe Project Saves Sakubva River". The poor management of water in Sakubva specifically, but in Mutare more generally, tempts one to cynically conclude that the City Council is extracting 0,7 cubic metres per second from Pungwe River to fill Sakubva River. Presently, Mutare cannot account for more than 50% of delivered water. That is to say, of all water delivered to consumers only 50% of that is accounted for as billed water. It is unclear what is happening to the rest of the water. What is clear, however, is the massive visible water losses in Sakubva which, one city engineer estimated to be 90% of all water delivered there (City Engineer, 11 July 2001). Water from the communal blocks flows 24 hours a day. In all the communal ablution blocks taps without heads can be found. Sometimes residents use small sticks of sugar cane or rags and elastics to stop the flow from open pipes. These 'conservation' measures are rare, however. Tap heads are sold in the open market. Usually, they are melted down into coffin handles. Sometimes the entire fixture is removed and sold on the open market, often ending up in wealthier home-ownership dwellings. The Sakubva situation shows that the management of water scarcity by supply-oriented projects raises many more questions than it provides answers. "Supply" for example, does little to alter problems of access. Indeed, it can create other problems – e.g. water-borne diseases – unanticipated in the rush to "secure" a steady supply.

6. WATER DEMAND MANAGEMENT IN SAKUBVA

In ***Water Resources Management Strategy for Zimbabwe*** (2000), water demand management is defined as an approach that aims to reduce, restrain or reschedule the demand on water resources. This stems from the realization that water is a finite resource which over the decades has become increasingly scarce. The failure to implement effective, long-lasting and community approved water demand management strategies by the City Council of Mutare compromises the principles of equity and efficiency, which is at the core of the new Water Act. For example, demand management focuses solely on punitive control measures – shutting off supply in the face of non-payment or vandalized services. In addition, there is little recovery of costs for water supplies as water is under-priced. As such, water services cannot be improved or extended to other areas due to shortfalls in revenue.

6.1 Water pricing in Sakubva

When setting the price for water the stated guiding principles are "water as an economic good" and "users pay" (WRMS, 2000). This position reflects the Hague's World Water Vision: "The single most immediate and important measure is the systematic adoption of full-cost pricing for water services" (in Kasrils, 2001: 52). But Zimbabwe is a deeply unequal country. To "provid[e] access to basic clean water supply is a direct attack on poverty" (Kasrils, 2001: 52). To this end, the City Council in April 2000, adopted a mixed fixed/block tariff structure to ensure that people of different social status have equal access to basic safe water and costs are recovered from those who use more water. The block tariff structure of Mutare was developed with the assumption that not everybody has metered water there. The low flat monthly rate is charged for water in areas with communal blocks. The block tariff structure only applies to areas where people have a metered tap. The low flat rate in these areas of Sakubva has jeopardized the principle of managing water by demand, as this encourages the inefficient use of water there.

In sections where people use communal blocks, a flat rate of approximately Z$500/mth for all services is paid to the City Council. This amount includes water, refuse collection, rent, the management of communal toilets and property tax. In one "household", one can find that there are +/- 7 families renting shacks and spare rooms (if there are any). In a situation in Matida flats (a 4-story building in NHB), it was found that an average of four families share one room. This means that the other three families are "free-riders" as they pay nothing to the city council for the services they get. Rather, they pay Z$400 rent to the landlords/ landladies. This payment makes them feel entitled to use the common block facilities and to any other service rendered by the city council. It is clear the erection of shacks in Sakubva is encouraged by the low flat rates the landlords/landladies are paying City Council and the substantial amount of money to be made by renting space. Leaseholders, paying Z$500-00 per month for all services -- an amount raised from one tenant -- are "stealing money" from the City Council. Overcrowding strains all resources and services.

The flat rate system also encourages commercial water use in Sakubva. For example, many people are using water from the communal blocks (meant for primary uses) for brick-making, hairdressing and other businesses. Sakubva is a place of entrepreneurs. A five minute walk is enough to spot several small businesses, the most visible of these being "spaza" shops, hair saloons, carpentry shops, and nurseries. Seven brick and tombstone-making businesses were identified there. These businesses use enormous volumes of water yet entrepreneurs pay no additional costs. As a result they accrue considerable profits. For example, in a brick-making business where more than 500 liters of water are used daily, a tombstone is sold for Z$2 500, Z$20 per airbrick, Z$30 for a brick and Z$100 one brick wall, yet all services cost only Z$ 500/mth. One person interviewed in the brick and tombstone-making business expressed a willingness to pay for water provided it is brought nearer to his working place. The communal block where water is accessed is approximately 50 meters away from the work place.

In areas like OTS, most people are growing vegetables along the Sakubva River for subsistence and selling. While it is a fact that this entrepreneurship has been influenced by a high rate of unemployment in the area, one can say it is also facilitated by the availability of free water.

6.2 Water metering and monitoring in Sakubva

In some sections of Sakubva water is metered and in some it is not. The existence of effective water metering is fundamental to proper water management and pricing as Goldblatt et al. (1999) stress. In Sakubva there is no effective water metering and monitoring. This is more so because many existing meters are no longer working. Whereas residents feel they are charged unfairly as meter readers make estimations, City Council freely admits that these estimations are usually nothing more than 'wild guesses' and gross *underestimations* (interview, Chirawu). Until water in the whole of Sakubva is metered, water pricing will remain contentious. The City Council of Mutare needs to weigh the costs of meter installation, maintenance, regular reading and billing against the benefits.

7 PROPOSED SOLUTIONS BY THE CITY COUNCIL OF MUTARE

7.1 Developing water points

This method has been adopted from Zambia where an official from the City Council of Mutare says it is doing well. Under this proposed strategy, City Council will sell water to one person and this person will be responsible for the management of water at a water point. Residents will use water tokens in order to buy water from the water points. It is anticipated that water at water points will cost Z$8 per cubic meter. Thus it will cost a household Z$4 a day since a household is thought to use +/- 400 litres/day. However, the interviewed engineer believed that Z$4 is too much since most Sakubva residents live "below bread line". If the engineer is correct, implementation would mean that people who cannot afford Z$4-00 per day would not get water. There are many other questions that beg answers: How many and where will water points be located? On average, how far will they be from households? How can one carry 400 litres of water everyday. And who is to do the fetching? Is this to be another task heaped upon women? Far from a viable solution, water points appear to us as nothing but another neo-liberal non-answer to a complex and serious problem.

7.2 Introducing levies on shacks

Following the failure to demolish them in 1995/6, the City Council has proposed to levy all shacks in Sakubva. Council has proposed monthly fees of Z$75 and Z$50 for metered and non-metered services respectively per residential shack. The owners of commercial shacks are to pay Z$300-00 and Z$200-00 for metered and non-metered services respectively. Attempts by the City Council in June 2000 to enforce service charges on shack dwellers backfired after the Mutare Residents' Ratepayers Association (MRRA) led a successful protest against the proposed rates. However, the City Council, through Kenneth Saruchera, Chairperson of the community services, housing, health and education committee, indicates that it is unlikely to reverse its decision this time. The municipality is just waiting for the relevant by-laws to be put in place. Geoff White, the leader of MRRA reacted to the above proposal by indicating that they were opposed to the idea of shacks dwellers paying a uniform amount. "He said the municipality should devise a mechanism to determine those who should pay and those who could be spared. Many of the people who live in shacks cannot afford the levies" (www.dailynews.co.zw/daily/2001/August/August9/13082.html).

The issue of levies on shacks highlights quite nicely the difficult political climate within which Mutare City Councillors operate. The executive committee of MRRA is composed of chairpersons from both high- and low-density areas. The MRRA is an influential community association. It demonstrated legal muscle when it won a court case which declared illegal rate increases which the city had declared earlier in 2001. This militant organization has always been a source of controversy in Mutare, and the whole issue has become very political. One of the association executive members in Sakubva indicated that City Council perceives the MRRA as a political movement rather than a ratepayers' association. The leader of the MRRA, Geoff White, is a well-known local firebrand who, while himself white, quite commonly plays the 'race card', characterising issues before City Council in terms of race/class binaries. Hence, White's argument is that subsidising Sakubva is the least low density suburb residents and commercial water users can do for people in poverty. Politics aside, this strategy of levying shacks has negative and positive implications. On the positive side, it will generate money for improved services. On the negative side, this strategy does not change the fact of overpopulation. A per shack levy is not a disincentive to live in Sakubva. In any event, politics may make this initiative impossible to carry through.

8. SOME ALTERNATIVES?

8.1 Proper planning for population growth

For the ever-increasing population of Sakubva, projects or programmes have to be properly planned now as failure to do so will only make matters worse. Currently, for the whole of Mutare there are more than 23 000 people on the housing waiting list

www.dailynews.co.zw/daily/2001/August/August9/13082.html). Effectively dealing with challenges of population include several related aspects. First, controlling influx. Second, providing space. Third, dealing with natural increase. In order for the City Council to recover the costs for the services they provide, ***registration of families*** with the City Council can help. Instead of levying a shack, every registered family can be made to pay a certain amount of money for the resources they use. In Sakubva there are many families in one stand, sometimes having two or more families in one shack . Levying a shack in a stand would not help reduce overcrowding. Absentee landladies would still make a huge profit. Registration may discourage influx of illegal immigrants. In terms of providing space, the creation of outlying suburbs has not been a total failure. Incentives should be put in place – e.g. site and service; lower property levies; tax holidays -- encouraging people to move to other suburbs. Key here is to raise revenue in the case of registration so that it may be used not only to improve services but to subsidise movement out of Sakubva into outlying areas. Changes must also be made to the property tax/service structure. Where leaseholders are actually absentee landlords, properties should be considered commercial ventures and taxed accordingly. In terms of natural increase, a concerted outreach programme must be developed so that women in Sakubva are educated about choice. Evidence shows that where women have choices made available to them, they have – regardless of social class – chosen to have fewer children and/or to space out births over a longer period of time.

8.2 Community participation at all levels of water resources management

Most Council strategies have failed because they have been met with community disapproval. Historically, few City Councils anywhere have involved local people in the planning of resources management. When asked about the extent to which the community has been involved during the development of present initiatives, one of the engineers in the City Council said “We do not think we can get a better method from them”. The residents of Sakubva discard these initiatives because they do not feel they own them. The recent discontents by MRRA around the levying of shacks is a vivid example of this. A continuing focus on punitive measures combined with an adversarial style of politics driven by particular individuals has led the people of Mutare and the township of Sakubva down a dead end road. Politics is about choices: people can choose to act differently in order to create partnerships and better working relations.

8.3 Training of community members

Training is important and has been effective elsewhere. For example, in the case of townships in South Africa, residents have been trained as community plumbers and as pump mechanics. This can save both water and money as much money is used to purify the water that is lost through leakages. It can also instill a sense of ownership within the community, or among members of the community.

8.4 Involvement of the youth in community mobilization

In Sakubva, the youth – particularly unemployed youth -- are playing an important role in the campaign against the spread of HIV/Aids and drug abuse. They are doing this by mobilizing their peers through sport, and counseling those who are already HIV positive. These youth can also play a crucial role in mobilizing the community of Sakubva towards effective use of water and, perhaps, in policing water points/ablution blocks. Ways should be devised so that youth benefit both monetarily and through acquiring skills – purely voluntary activities will eventually wither and die.

8.5 Waste utilization in Sakubva

In the streets of Sakubva heaps of rubbish are a common, unfortunate sight. This organic waste can be used productively by individual households for manures for their vegetable gardens which are prevalent in Sakubva. Community gardens can also be developed and fertilized through these wastes which at the moment are a health hazard to the community.

8.6 Involvement of non-governmental organizations (NGOs) in the management of water

Perez (2000:13) observed that a major constraint to providing environmental services to the urban poor is the lack of political will, legal mandate, and technical and institutional capacity of municipalities. In the rural areas of Zimbabwe, NGOs are playing an important role in the management and extension of water and sanitary facilities to the rural poor. The involvement of SNV and Plan International in Nyanga and Mutasa shows that NGOs can fill the gap. In Nyanga rural district, NGOs are financing water and sanitation programmes. For example, they are financing borehole drilling projects and well-cleaning projects. They also train community members on how to manage these water points. Many NGOs are socially committed, flexible and able to improve their ability to work effectively with poor communities. The key to their success is setting aside their normal NGO role as “implementor” for a new role as “facilitator” or “broker” between the informal communities and the formal private and public sectors (Perez, 2000: 13).

If Mutare City Council or, indeed, Zimbabwe national and provincial government remains paralyzed by politics, the only way around may be to invite NGOs in to do what government should be doing. Communities or NGOs themselves may need to initiate these sorts of linkages. Community leaders in Sakubva could establish a web-site, perhaps, and solicit ‘linkages’ for specific projects (sanitation, water supply) – not only with NGOs but universities, cities, companies and the like. Once again, the youth of Sakubva could play a crucial role here.

8.7 Involvement of women as common block managers.

Experience in most rural areas of Zimbabwe shows that common pool resources such as boreholes and wells can be effectively managed by water users themselves. In these areas, water point managers are elected. Duties include ensuring that water points are clean, reporting leakages and determining the extent to which people can practice subsistence farming around the water points. These people are usually women because they are the primary users of water, water has historically been associated with the ‘women’s domain’ in Africa and many women do not have formal-sector, off-farm jobs. It is however important to draw the Khayelitsha (Cape Town, South Africa) experiences into perspective here. This experience is interesting because Khayelitsha shares many similarities with Sakubva. In Khayelitsha, in areas where they use common blocks there are common blocks managers. Whoever uses the common block pays 10 cents to the manager who in turn provides a piece of toilet paper.

In Sakubva women can also play a crucial role in the management of the common blocks not merely because they spend most of their time using the common blocks for doing washing, fetching water for drinking purposes, bathing, etc. Empowering women as managers should mean giving decision making power – including fees levied and distribution of profit – to those who are primary users *because they are primary users, not because they are women or because it is the ‘women’s domain’*. Too often ‘community empowerment’ means burdening those already over-burdened with ‘voluntary’ tasks. Because women are relegated to the ‘private domain’, these ‘social’ activities too often fall to them. In other words, the language of ‘empowerment’ does nothing to alter existing structural inequalities. If water point management is to succeed in Sakubva, then, some creative combination of government (capital, technical and human resource) support, user-pay fees, and monetary- or other-incentive structure for (female) managers must be put in place. To succeed in the long-term these programmes must be something other than simply relief-oriented, ‘food for work’. In addition, the driving force behind them must be something other than abdication of responsibility on the part of government, at whatever level.

9. CONCLUDING REMARKS

Water resources and sanitation facilities are under stress in Sakubva. Addressing these problems is increasingly difficult. At the core is a complex matrix of population movement primarily by impoverished peoples, rent-seeking behaviour on the part of leaseholders, historically difficult relations between Mutare City Council and residents of Sakubva, and self-seeking, destructive behaviour on the part of politicians. For these reasons, Pungwe water has been no ‘solution’ to the problems of the township. Sustainable solutions, in our estimation, rest with the youth and women of Sakubva, sympathetic voices within City Council (like the Department of Health), and creative individuals and organisations in the wider world.

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The use and management of water in the Likangala irrigation scheme complex in southern Malawi: Some preliminary findings

Wapulumuka O. MULWAFU & Bryson G. NKHOMA

University of Malawi, Chancellor College, P.O. Box 280, Zomba, MALAWI
Phone (265) 524-222 Fax: (265) 524-046

Wmulwafu@chirunga.sdnp.org.mw

ABSTRACT

This paper examines the uses and management of water for agriculture in Lake Chilwa catchment area in Zomba district of Southern Malawi. It focuses on the Likangala Rice Irrigation Scheme complex situated along the Likangala River. The scheme is one of the largest self-help schemes. Established in the late 1960s by the government to meet the growing demand for rice, the scheme contributes greatly to the agricultural industry of the country. Besides, the scheme was established to ensure maximum utilization of Malawi's largest wetland, which, due to its hydromorphic soils and the littoral floodplains, does not favour the production of traditional upland seasonal crops such as maize. The scheme's overdependence on water from the Likangala River has attracted a considerable degree of academic interest in the use and management of the River to ensure that there is equity and efficiency for both productive and domestic users. The paper focuses on four main issues: the historical development of the scheme, the distribution of water to farmers, social relations, and the overall contribution of the scheme towards the social and economic development of the area and the country in general. The paper contends that the growing population of the basin and the increase in the number of formal and informal smallholder farmers, contributes greatly to the growth of competition and conflicts over water, which tends to undermine the economic potential of the scheme. Furthermore, the paper provides clearest indication of the need for a realistic and informed water management policy and strategy to solve the growing problem of social inequity without necessarily compromising the production of rice in the scheme.

Keywords*: *agriculture; irrigation; water; rice; scheme; rehabilitation.

1. INTRODUCTION

This paper examines the use and management of water for agriculture in the Lake Chilwa catchment area in the Zomba district of Southern Malawi. It focuses on the Likangala Rice Irrigation Scheme Complex which is situated along the Likangala River. Since Likangala is the most heavily used rivers in the entire catchment, stiff competition exists on access to and use of water resources. The establishment of the scheme has increased competition for water which requires a more systematic management strategy. The paper contends that the growing number of different interest groups in the scheme and the Likangala River per se contributes greatly to the growth of competition over water which, in turn, tends to undermine the economic potential of the scheme. This competition is reflected in the manner in which the canals are being managed. One of the greatest challenges of irrigated agriculture in the area remains that of how to increase agricultural production without necessarily destroying the health of the river, farmers and aquatic systems. The paper suggests that there is need for a more realistic and informed water management policy and strategy to solve the growing problem of social inequity without necessarily compromising the production of rice in the scheme.

Research for this paper was conducted with financial support from the Water Research Fund for Southern Africa (WARFSA) and USAID under the Broadening Access and Strengthening Input Market Systems (BASIS) Collaborative Research Support Program. Data collection involved interviews, focus group discussions and a review of literature. Fifty households both within and outside the scheme were sampled for interviews. Focus group discussions were also held with farmers and some members of staff at the scheme.

Significance of Irrigation in Malawi

The importance of irrigation farming for increasing agricultural productivity has long been recognized. Most recently, the Ministry of Agriculture has been using phrases like "intensifying" or "revolutionizing irrigation farming" in a bid to avert food shortages in the country.[1] In countries with erratic or inadequate rainfall, irrigation provides the surest and most efficient way of providing water for agricultural production. In Malawi, irrigation has not been fully developed in spite of the recognition by government of its significance for enhancing economic development.[2]

The total area of irrigated land in Malawi is estimated at 57,040 hectares, this figure having just gone up from 24,048 hectares in 1994.[3] According to government, this expansion has largely been due to adoption of motorized and teadle pumps by smallholder farmers. But it also reflects the growing realization of the importance of irrigation for promoting Malawi's economic development. Some of the largest irrigation schemes in the country include Lueya in Nkhata Bay, Nkopola in Mangochi, each cultivating about 800 hectares. Most recently, the 800 hectares Bwanje Irrigation Scheme was launched in May 2001 at the cost of K1.3 billion or $17 million with financial assistance from the Japanese Agency for International Cooperation (JICA). The scheme has a total number of 2,240 farmers, of which 760 are women.[4] Each farmer works about 0.4 hectares of irrigated land. It is hoped that this scheme will be able to produce a variety of food and cash crops to generate income for farmers as well as contribute to economic development of the country. Irrigation is also widely used in sugar production in the country's two largest estates of Nchalo and Dwangwa. Small dams and irrigation facilities exist on some private estates in the country, particularly those involved in tea, coffee and tobacco production. Given the large number of wetlands and other areas that could be productively used for agricultural production, the potential for expansion still exists in the country. For example, the Lower Shire Valley has long been recognized as a potential area for the development of irrigation. A government minister recently said that the country needed about 20,000 hectares of well-irrigated and efficiently managed land to yield surplus in food crops.[5]

The rapid population growth and the recurrence of drought the country has experienced in the past two decades calls for a policy shift from rain fed to irrigated agriculture. Irrigation has the potential to expand cropping opportunities for smallholder farmers in which a wide variety of crops could be grown in both the dry and wet seasons. This cropping approach can contribute to poverty alleviation and also improve the nutritional status of the people in the country. To this effect, the government has made some strides in the right direction by drawing up an irrigation policy that places much emphasis on smallholder irrigation farming.

The most critical aspect for the success of irrigated agriculture is the use and management of water in the irrigation schemes. The agricultural productivity and the relationship among farmers depend

[1] *The Nation* Newspaper of 30 August, 2001 "Ministry Intensifies Irrigation Farming", p.3 of the Agriculture Supplement.

[2] The Department of Irrigation states that its mission is "to manage and develop water and land resources for diversified, economically sound and sustainable irrigation and drainage systems under organized small holder and estate management institutions and to maintain an effective advisory service".

[3] Reported in *The Nation* Newspaper of 30 August, 2001 "Ministry Intensifies Irrigation Farming", p.3 of the Agriculture Supplement. See also Kaluwa, P.W.R., F.M. Mtambo and R. Fachi, The Country Situation Report on Water Resources in Malawi (Lilongwe: UNDP/SADC Water Initiative, 1997).

[4] Reported in the *Daily Times* and *Nation* of 20 May 2001.

[5] See *The Nation* Newspaper of 30 August, 2001 "Ministry Intensifies Irrigation Farming", p.3 of the Agriculture Supplement.

greatly on water.[6] This is why it became necessary for us to systematically analyse how water is managed and the kind of relationships that are shaped as the farmers and other outside users interact with each other in attempt to share water for both domestic and productive activities.

2. DEVELOPMENT OF THE LIKANGALA RICE IRRIGATION SCHEME COMPLEX

After independence in 1964, the Malawi government established a number of rural development projects with the idea of modernizing agriculture and increasing peasant productivity. Three pilot projects were set up in Chikwawa, Salima and Karonga districts as agents of rural development. Unemployed youths were ideally supposed to be integrated into agricultural development through the Malawi Young Pioneers (MYP) that operated settlement schemes throughout the country. Unfortunately, these schemes were politicized so that by the time the country was undergoing political transition in the early 1990s, most of the schemes were in a moribund state.

Irrigation schemes were a significant component of Dr. Banda's development strategy to promote rural development.[7] Throughout Banda's rule, irrigation schemes served not only as means of increasing agricultural productivity but also as training bases for the youth of the country in various vocational skills. The Malawi Young Pioneers movement spearheaded this idea. Dr. Banda's government established settlement/irrigation schemes in such places as Wovwe, Hara, Limphasa, Likangala and Nkhate. In most cases, these schemes offered training and employment opportunities to primary school graduates.[8] There is a general perception that under the management of the MYP, these schemes run efficiently and productivity increased. It was in the interaction with the MYP that farmers were able to learn and comply rigorously with the regulations and discipline required of irrigated farming in the scheme.[9]

Likangala Rice Irrigation Scheme, one of the largest self-help schemes in the country, was established in the late 1960s with the aim of meeting the growing demand for rice as an alternative staple crop in Malawi. The scheme also sought to ensure maximum utilisation of Malawi's largest wetlands which, due to its hydromorphic soils and littoral flood plains, does not favour the production of traditional upland seasonal crops such as maize.

Likangala Scheme is a complex set of five schemes namely, Tsegula, Njala, Chilikho, Khanda and Likangala proper, three of which get water from the Likangala River itself. Likangala River, with its source on the Zomba plateau, passes through the urban areas of Zomba Municipality and a number of estates before emptying its water into Lake Chilwa, an inland drainage lake situated to the southeastern part of Zomba district. Located downstream, a few kilometres before the river joins the lake, the scheme is the last institutional user of water from the Likangala River.

The scheme has a total of 405 hectares of land and, out of this figure, 397 hectares are irrigable. Divided into 15 blocks, the scheme provides farming land to 1300 farmers, of whom 260 are female heads of households.[10] This number represents 97% of the people from the neighbouring villages,

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[6]Dumisani Magadlela, "Whose Water? A Look at Irrigators and Catchment Farmers' Watered Relations in Nyamaropa" in Manzungu, E., A. Senzanje, and P. van der Zaag (ed.) *Water for Agriculture in Zimbabwe: Policy and Management Options for the Smallholder Sector* (Harare: University of Zimbabwe, 1999):153-167.
[7]Alifeyo Chilivumbo, "On Rural Development: A Note on Malawi's Programmes of Development for Exploitation" *Africa Development* Vol.2 (1978):41-55.
[8]The problem is that with the passage of time, the schemes became heavily politicized and tended to serve the interests of the country's leadership.
[9]Interview: Mr. M.B. Chilimbiro, the Scheme Manager dated 21 February, 2001.
[10]Interview: Mr. M.B. Chilimbiro, Scheme Manager, dated 21 February, 2001.

although some of them let out their plots to outsiders. The neighbouring villages are Ramsey I, Ramsey II, Chilikho, Mbalame and Makhasu.

Apart from the Likangala River, the scheme and the neighbouring villages have boreholes, protected and unprotected hand dug shallow wells and a few gravity fed taps constructed by the Domasi Rural Water Supply Programme. Most of the shallow wells, which also constitute the main water supply facilities are privately owned, but are freely open to the public for domestic purposes such as drinking, cooking, washing, and bathing.

There is one main canal, which connects the Likangala River to a network of small canals that further distribute water to the plots on the scheme. From these canals, water passes through a network of channels constructed at different points on the schemes to be channelled into the cultivating fields. The canals are about two kilometers long, 3 meters wide and 2 meters deep. They are maintained annually by the farmers under the supervision of agricultural officials and the scheme management committee (SMC).[11]

The management of the scheme is a combined force of the government and the farmers. The government encourages increased participation of the beneficiary farmers in the planning and decision-making process with the purpose of instilling a sense of ownership among them. This has become particularly critical now that the government intends to hand over the schemes to the farmers.

The scheme manager is a civil servant who, assisted by three extension officers, undertakes the overall management of the scheme in terms of providing technical and agronomic advice to the farmers. A scheme management committee (SMC) was formed to ensure maximum participation of the farmers in the management of the scheme. Consisting of ten members, two of whom are women, the committee is theoretically a powerful force to reckon with in the allocation of plots, settlement of disputes among farmers and other interested groups.

3. AGRICULTURAL PRODUCTION AT THE SCHEME

The desired output of irrigation development is increased food production, and as much as possible diversify away the predominant production of rice in the scheme. There are four varieties of rice grown in the scheme: *phusa 33*, *faya IET*, *4094* or *changu*, and *TCG 10*. Rice is generally grown in summer (September - March), even though, depending on availability of water, it can also be grown in winter (April - August). In addition, farmers are given the freedom to grow crops of their choice such as maize, vegetables, watermelons and sweet potatoes, especially in winter season.

Farmers obtain credit facilities for agricultural inputs such as fertiliser and seeds from private organizations such as Agricultural Development and Marketing Corporation (ADMARC) and Malawi Rural Finance Company (MRFC). About 25% of the farmers use organic fertiliser such as compost and *khola* manure to reduce the cost and also improve the natural fertility of the soils. Water from the Likangala River is generally enough for agricultural activities. But during times of water shortages the main canal on the Likangala River is closely regulated to allow more water to flow into the scheme. However, this brings the farmers at loggerheads with other users of water downstream. The income levels of the farmers in the scheme is generally much higher than those outside the scheme who, depending solely on rain, are vulnerable to drought and inadequate rainfall.[12]

[11] Fieldnotes: Noel Mbuluma dated 20 June, 2000.
[12] Interview: Mr. M.B. Chilimbiro< Scheme Manager, dated 21 February, 2001.

However, the farmers face a number of problems. The first one is that of unfaithfulness by some farmers when it comes to repayment of loans from MRFC. This has resulted in the withdrawal of the organization from offering credit facilities to the farmers. The situation is accelerated by the fact that the MRFC offers these credits to farmers as a group. This means that the failure of one farmer to pay back his/her portion of the credit results in the withdrawal of the organization to give the facilities to the entire group.

Secondly, the scheme is situated in an extremely low-lying land which makes it vulnerable to floods and water logging of the soil. Consequently, crops grown are sometimes swept away by floods. Those cultivating in the wet season sometimes fail to harvest their crops due to the increase of water that comes with the early heavy rains, and that the water logging attracts the spread of rice blast diseases common in *phusa 33*.[13]

The other problem is lack of a reliable market for rice, especially now that ADMARC has stopped buying farm produce. Consequently, farmers are depending on private traders who, besides their infrequent turn-up, do not buy in large quantities and insist on buying rice at low prices. This market unreliability makes farmers easily lose their bargaining power and resort to selling at self-fulfilling prices. Eventually, their financial gains does not correspond favourably with the cost of investment they make in the production of rice. This presents a major threat to the sustainability of rice production in the scheme.

The last problem is that of encroachment into the scheme by the original inhabitants who were resettled in other places when the scheme was first established. Some people have started claiming their land back. Although the issue was presented to the District Commissioner, the so-called original inhabitants of the land have started stopping the farmers from cultivating the plots and others have gone to the extent of actually growing rice in the scheme without prior approval of the SMC.

4. THE MANAGEMENT OF WATER IN THE IRRIGATION CANAL

The irrigation canal is an integral part of the management of the scheme. The success of the scheme at management, social, sanitation and production levels depends on the manner in which the canal is managed. The irrigation canal is what brings all these different aspects together.

Although the primary function of the canals is to distribute water to the farmers, the scheme management uses them as weapon of controlling various social and farming activities in the scheme. The canal, for instance, is constantly closed down to allow the farmers plant and harvest crops, clear their fields, and effectively carry out some maintenance work in the canal. Besides, the closing of the canal reduces water from the fields that may get over half a metre high in the rain season. Once the river is closed off to the scheme, more water is made available to other farms along the river downstream.[14]

The manner in which these canals are managed play a crucial role in shaping human and social relations in the scheme. In many cases, a number of misunderstandings and conflicts emerge among farmers in response to the technical implications of canal management. The freedom that the farmers are given to grow crops of their choice in addition to the conventional rice, for example, creates stress among farmers who require different quantities of water at different times for their crops respectively. This problem calls for a different approach in the management of water resources; an approach that incorporates proper water scheduling taking into consideration the water requirements of each crop

[13] Fieldnotes: Noel Mbuluma dated 17 November, 2000.
[14] Fieldnotes: Noel Mbuluma dated 7 March, 2000.

which at present does not exist. Studies elsewhere have shown that this is quite feasible. According to Manzungu and van der Zaag, the unacceptable long intervals and inequities among the Nyanyadzi farmers who collected as much water as they needed had to be avoided by formulating a time-based roster of irrigation in which each gets a precise time allocation, proportion to the land that a farmer owns and the crops he/she grows.[15]

The situation becomes worse during dry season and periods of droughts when the flow of water is too low to meet the farming needs of the farmers in the scheme. During these periods water distribution depends on the goodwill of farmers. In most cases, the farmers have to pass on water from one to another. In the absence of trust, the farmers begin to develop survival strategies that tend to undermine the rights of other farmers in accessing water. One of these survival strategies is to block the canals or dig trenches in the canals in order to increase the level of water to irrigate their plots easily and for a longer period of time. Our studies show that this tendency often results in the development of tensions among farmers with undesirable consequences. Where fighting is not possible, a kind of cold war develops among the farmers leading to the breakdown of communication and souring relations.[16]

Another source of stress is the increased interaction between institutional and public uses of the canals. Although the canals were constructed to facilitate agricultural production, people from neighbouring villages use them for all sorts of domestic and productive purposes such as washing, bathing, fishing, moulding bricks, cleaning maize before taking it to a maize mill. Others go to the extent of drinking water from the canal! Ferguson and Mulwafu argue that the dependency of the people on institutional sources overshadows the distinction between public and private provision, and the subsequent lack of clarity about priority of use and responsibility. They further argued that this use of water by the public could interfere with the effective use of water by the farmers.[17] As will be shown below, this has implications on the relationship among farmers and the villagers, on health and sanitation and the intensification of rural hardships as the farmers need the canals to be frequently closed and opened in order to effectively carry out their activities.

Because the use of water by the public interferes with the interests of the farmers, the scheme management constructed concrete terraces at two points on the main canal where villagers can bath or wash their clothes. In the past, water guards were employed to arrest those who failed to wash and bath at these points. However, the enforcement of these by-laws and restrictions has been crippled by, among other things, indigenous perceptions of the uses of water by both the farmers and the villagers. The villagers view water as a natural good which God provided for the benefit of all mankind and that no one should bar anybody from using it. This conflicting perception on the uses of water is generally acknowledged in the water literature. In the case of Zimbabwe, Dumisani Magadlela noted that there is a conflict between traditional ownership of water and modern legal and institutional rights.[18]

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[15]E. Manzungu, and P. van der Zaag, "Continuity and Controversy in Smallholder Irrigation" in Manzungu, E. and P. van der Zaag (ed.) *The Practice of Smallholder Irrigation: Case Studies from Zimbabwe* (Harare: University of Zimbabwe Press, 1996).
[16]Fieldnotes: Noel Mbuluma dated 20 March, 2000.
[17]See A. Ferguson and W. Mulwafu, "Decentralisation and Access to Water Resources in Malawi", Paper Presented at the BASIS Southern Africa Workshop, held at Magalieburg, South Africa from 23-25 July, 2001, p.23.
[18]See Dumisani Magadlela, "Whose Water?…." in Manzungu and van der Zaag (ed.) *The Practice of Smallholder Irrigation*, p.110.

What is problematic is the fact that the water in the canal is not good for human consumption and some domestic activities. The water in the canal comes from the Likangala river, which is heavily polluted with raw sewage and industrial disposals.[19] Moreover, there are no toilet facilities in the scheme and, since the farmers spend long hours working in the field, they presumably help themselves in the fields and canals. Our studies also show that some hospital staff, faced with the problem of inadequate water supplies, sometimes resort to washing beddings in the canals.[20]

The villagers as well as the farmers are aware of the pollution of the water, but still insist on using it. They argue that the water in the canal is available in a volume that is convenient for their activities. Second, that the water is not salty. Furthermore, they contend that since private owners of wells do not allow them to use their wells for productive activities, they have little choice but to use canal water. In view of this situation, it is not surprising that the Likangala Health Centre registers large numbers of people suffering from cholera, bilharzia, diarrhoea and typhoid fever.

Management of water resources in the scheme also involves conflicts between the different users, particularly when different parties find ways of securing water monopoly during times of drought and water shortages. Water scheduling and rationing that the SMC adopts in these critical times causes stress among farmers who more often than not engage into scrambling for water in the scheme.

Witchcraft accusations have also been levelled at some farmers for withholding rains. Anecdotal evidence shows that one farmer was accused of withholding rains so that he could harvest crops grown during dry season. The crops of this particular farmer had not completely dried in the field. So although the rainy season had come and heavy clouds had gathered, no rains could fall down. People in the area began to suspect that accused farmer was responsible for failure of the rains to fall down.

Although the SMC is a body that is entrusted with the responsibility of settling disputes among farmers, existing social relations also have a mitigating effect on the way such matters are resolved. Some SMC members show a great deal of sympathy and favouratism when trying cases involving farmers who are related to them.

Rehabilitation Programme

The change in the political system in the country and the withdrawal of government subsidies for large-scale irrigation schemes has led to a change in thinking about the management of irrigation schemes. The new democratic government did not favour the idea of maintaining schemes that were connected with the oppressive activities of the MYP. But macro-economic factors also had an influence on this; neo-liberal theories of development tended to promote market-oriented principles in the management of schemes. This meant that irrigation schemes could no longer function in the same way they did before.

As stipulated in the National Irrigation Policy and Development Strategy (June 2000), the government has embarked on ambitious programme of preparing schemes for rehabilitation and eventual handing over to the beneficiary farmers. This costly exercise will involve the reconstruction of the canals, building water control structures, head works for diverting water, and the maintenance of roads to improve accessibility of the schemes and the training of farmers.

[19] See G. Chavula and W. Mulwafu “Hazardous Water: An Assessment of the Quality of Water Resources in the Likangala Catchment Area for Domestic Purposes” (Unpublished Paper, 2000), p.7-8.
[20] Fieldnotes: Noel Mbuluma dated 1 March, 2000.

This process will require a substantial amount of financial and technical resources, which the government does not have. A senior government official emphatically pointed out that "we shall not hand over the schemes anyhow. We are rehabilitating infrastructure, like head works and main canals in the schemes so that we leave the schemes in the hands of the farmers in good shape as some of them were in dilapidated condition."[21] Consequently, the donor community has been approached for assistance. At the moment, donor funding has already been identified for the three pilot schemes of Wovwe, Domasi and Nkhate. The main sponsor is the International Fund for Agriculture Development (IFAD). For Likangala Scheme, no donor has as yet been identified. The other schemes scheduled for rehabilitation and handing over to farmers are Lufira, Hara, Bua and Lufuwa.

The government is also in the process of elevating some small irrigation farms into high performance ones, such as Khwisa Rice scheme in Balaka, Njolomole in Ntcheu, and Songani in Zomba. The restructuring of these schemes entails the provision of education on irrigation to local farmers as well as inputs in order to sustain the schemes. Currently, there are over 40,000 smallholder farmers cultivating in public irrigation schemes, but these will soon be allowed to manage the schemes on their own in line with the new policy.

5. Conclusion

By way of concluding, it is important to note that irrigated agriculture has become the last resort for increasing agricultural production in a country faced with a recurrence of drought and rapid population growth. However, the expected output of agricultural production is mitigated by factors that have a social dimension as noted in the case study. The management of irrigation canals in the Likangala rice irrigation scheme influences the human and social relations among farmers, between farmers and the villagers, and also between farmers in the scheme and those outside the scheme. These relationships have a direct effect on the production of crops in the scheme. Where the management of canal is poor, especially in critical times of drought and in dry season, the commonest result is breakdown of communication among the parties concerned; a situation that stagnates the development and productivity of the scheme. Entrusted with the management of conflicts in the scheme, the SMC faces the challenge of ensuring fairness and equity without necessarily compromising the ordinary social relations the members have with plot owners on the scheme.

The other problem which the study noted is the failure of the government to establish means of protecting the environment as stipulated in the irrigation policy. While the irrigation canal was constructed primarily to channel water into the fields, it is also providing public service which is essential for the social and economic development of the area.

Our studies have shown that the water in the canal is not safe for domestic uses. Failure to abstain from using water from the canal which often is enhanced by the absence of reliable sources of water has resulted in the spread of water borne diseases among the farmers and the villagers. The constant closing down of the canals again is responsible for the destruction of aquatic life like fish which is essential for human and economic development. The challenge presented here is how to protect the health of the people and aquatic life in a way that would not adversely affect the production of rice.

[21] *The Nation* Newspaper of 30 August, 2001 "Ministry Intensifies Irrigation Farming", p.3 of the Agriculture Supplement.

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Isolation and screening of microorganisms for potential application in remediation of effluent water from the pulp and paper industry

Caleb C. MUZARIRI[1], Josephine MAPINGIRE, James MAZORODZE, Lorraine MANDIKUTSE

Department of Biochemistry, University of Zimbabwe, P.O.Box M.P.167 Mount Pleasant, Harare, Zimbabwe

[1] muzaric@sci.uovs.ac.za

ABSTRACT

White-rot fungi were isolated from woodlands in two different temperate regions of Zimbabwe. These are namely the dry, hot region of Chirundu and the Zambezi valley woodlands inhabited mostly by Mopani, Mukwa and Muunga indeginous trees, and the wet, cool, humid region of Chimanimani, Bvumba, Bhema valley and peri-urban Mutare inhabited mostly by Eucalyptus, Pine and Wattle plantations. The thermophiles were isolated from Zimbabwean hot water springs. The springs are at temperatures of 65 ^{0}C, 70 ^{0}C, 75 ^{0}C, 80 ^{0}C and 100 ^{0}C respectively and are located in different regions of the country. All the fungi and bacteria so collected were screened for cellulase, laccase, lignin peroxidase, manganese peroxidase and xylanase activities. From the enzyme activities, it is observed that of the dry, hot region collections, 48.3% of the microorganisms produced laccase, 70.7% produced lignin peroxidase, 100% produced xylanase in extremely low or very high amounts, 24% produced manganese peroxidase and 98.3% produced cellulase also in low or high amounts depending on species or strain. Whereas of the wet, cool region collections, 31.3% produced laccase, 26.9% produced lignin peroxidase, 99.2% produced xylanase, 81.3%produced manganese peroxidase and 31.3% produced cellulase. Of the presumptive thermophiles, 34.3% produced laccase, 78.1% produced lignin peroxidase, 100% produced xylanase, 28.1% produced manganese peroxidase and 78.1% produced cellulase. The five enzymes listed here are important lignocellulose biodegrading enzymes for the bioremediation of the pulp and paper industries' effluent water towards decontamination and re-cycling.

INTRODUCTION

The pulp and paper industrial effluent water is heavily polluted with lignin, inorganic salts and foul smelling hydrogen sulphide that arises from the pulping process that uses sodium sulphite for the extraction of lignin from the pulp. Inorganic salts can also accumulate in the effluent water from the use of sodium carbonate as an alternative method of extracting lignin. The removal of lignin from the eucalyptus or pinewood is a key operation in the manufacturing of high value paper products. Lignin is a highly insoluble polymer of aromatic phenolic molecules that form an extensive cross- linked net work within the wood and the plant cells generally. The lignin thus discharged into the effluent water is exposed to subsequent reactions with chlorine from the municipal water treatment works or chlorine from the textile bleaching industries, to form recalcitrant chloroorganic compounds that are highly toxic or carcinogenic. In the large pulp and paper manufacturing plants, the bleaching of Kraft and suphite pulps involves the use of a number of bleaching chemicals including the environment polluting chlorine containing reagents such as elemental chlorine, chlorine dioxide and sodium or calcium hypochlorite (Fengel and Wagner, 1984). The chlorine radicals arising from such bleaching effluent react with lignin to form recalcitrant chlorolignins as well as low molecular weight chlorinated phenols, catechols and guaiacols which are toxic or carcinogenic (Smit *et al,* 1995). The amount of toxic pollutants in the industrial effluent water may be minimised through biotechnological means (Christov and Prior, 1998).

The major Zimbabwean paper milling and pulping plant, uses the neutral sulphite pulping process and not the kraft sulphite process which is commonly used in the larger South African pulp and paper plants. It releases into the water effluent, 180 000 cubic metres per annum of a black lignin-containing liquor which arises as a 25% by weight extract from eucalyptus wood or 35% by weight extract from pinewood batch pulping processes respectively. The other cause of the effluent water pollution at the plant is the unrecoverable inorganic salts that arise from the use of the sodium sulphite and alkali such as sodium hydroxide or calcium hydroxide during the pulping process. For plants that produce a minimum of 800 tons of pulp a day, a known technology exists for the recovery of inorganic salts economically. This involves concentrating the effluent liquor to 50% by weight of dissolved solids. This mixture with lignin burns like fuel. It is burnt and the recovery of 95% inorganic is accomplished for re-use in the plant. However, only the insoluble lignin component is accounted for in the burnt concentrate, whereas the more water soluble lignin component still escapes with the effluent water arising from the concentration process.

An extensive isolation and screening programme was initiated to select a variety of microorganisms that produced enzymes of potential use in pollution control. The targeted microorganisms were white-rot fungi and thermophillic fungi and bacteria. The sources of the white-rot fungi were the ecologically diverse woodlands of Zimbabwe and the sources of thermophiles were the high temperature hot water springs located in different regions of Zimbabwe, some as far apart as 500 kilometres from each other.

These microbial isolates would also serve as a resource pool for enzymes with potential application in other industries affected by similar organic pollutants such as the textile dyes industry, the oils and paints industries, where laccases are also known to biodegrade the dyes and paints effluent residues.

White-rot fungi are generally known to produce from their cellular metabolic processes, both lignin biodegrading and cellulose hydrolysing enzymes namely; cellulases, laccases, lignin peroxidases, manganese peroxidases and xylanases. Some thermophilic fungi have been shown to produce thermostable xylanase (Kalogeris *et al*, 1998) and cellulase-free xylanase (Gomes *et al,*1993) and several thermophilic anaerobic bacteria have been shown to produce xylanolytic enzymes that convert xylan and hemicellulose wastes to ethanol (Arhing *et al,* 1996). The catalytic actions of these lignolytic and xylanolytic enzymes, makes them potentially good tools for effluent water pollution control in the pulp and paper industry. They can be used either for direct biodegradation of chloroorganics, hemicellulose and cellulose sludge pollutants (Kondo, 1998) or as for xylanase, as environment friendly biobleaching agents to replace chlorine-containing reagents of chemical bleaching (Christov *et al,* 1996).

MATERIALS AND METHODS

1. Isolation of white-rot fungi and thermophilic microorganisms

The dry, hot region collection of white rot-fungi was done in the very hot and dry areas of Chirundu and the Zambezi valley in Zimbabwe. The hot water springs were incidentally also located in the usually hot and arid areas of the country. Microbial water samples from the springs were collected in previously autoclaved and clean bottles. Some hot water springs recorded a temperature of 100 ^{0}C, others were 80 ^{0}C, 75 ^{0}C, 70 ^{0}C and the lowest 65 ^{0}C. Naturally grown and sun dried fruiting bodies of the white-rot fungi were collected from live trees, tree stumps and logs of mostly hardwood trees, namely the *Mopani, Msasa, Mukwa, Muunga* and *Muvanga* commonly found in the dry, hot regions.

Collection of white-rot fungi from the wet, cool, humid regions was carried out in the areas of Chimanimani, Bvumba, Bhema valley and Mutare peri-urban. The fungal fruiting bodies were isolated from mostly the exotic *Eucalyptus, Pine* and *Wattle* tree plantations and some softwood indigenous trees. A number of fruiting bodies were collected from wet dead wood surfaces, from the live trees and wet tree stumps and others were collected from the decaying humus in the soil.

To obtain pure cultures of fungal fruiting bodies, candle flames or spirit lamps were used to sterilise scarpel blades, which were used to open up clean surfaces within the fruiting bodies by incision of small sections. Then after, a clean tissue of about 10 mg was lifted for subsequent inoculation onto the agar plates. Each inoculated petri dish was tightly sealed with parafilm. The pure isolates were left to incubate at room temperature for at least 3 days after which fungal growth was observed.

The malt extract agar medium for mesophilic fungal isolation contained the following per litre volume; 12.5 g maltose, 2.5 g dextrin 1.0 g glycerol, 2.6 g peptocomplex and 17 g Agar Bios LL. Isolates were purified by successively streaking out three to five times on sterile agar plates. The final isolates were stored on malt extract agar slants.

2. Screening for lignolytic and xylanolytic enzyme activities

Mesophilic fungi were grown in a medium containing (per litre distilled water):
10 g yeast extract, 0.25 g citric acid, 5 g $(NH_4)_2 SO_4$, 5 g K_2HPO_4, 0.5g $MgSO_4.7 H_2O$ and 0.02 g $Ca Cl_2. 2H_2O$. The mixture was placed in a 1litre flask and made up to the mark with distilled water.
Aliquots of 10ml each were then dispensed into McCartney bottles and autoclaved.

Inoculation with the mesophillic fungi was carried out as follows: Using a sterile sharp scarpel, a 0.1 g section of a sun-dried fruiting body was bathed in 99.9% ethanol for 2 seconds, then flamed on candle flame for 2 seconds and quickly placed in the autoclaved, labelled McCartney bottle with the above medium. The inoculated McCartney bottles were incubated at 32 ^{0}C for the mesophilic fungi and at 50 ^{0}C for the thermophiles, each for at least 7 days before assay for enzyme activities was started.

Using the Jenway UV/Vis Spectrophotometer, cellulase production by the microorganisms was measured at 620nm as previously described (Enari and Niku-Paavola, 1988). Laccase activity was assayed at 420nm (Li *et al,* 1999). Lignin peroxidase production was determined using veratryl alcohol as substrate (De Jong *et al,* 1992). The assay at 238 nm (Gold and Glenn, 1988) was used to determine manganese peroxidase activity. In agreement with Jeffries *et al*, (1998) and as also confirmed by Muzariri and Prior (1999), xylanase activity was measured by the arsenomolybdate method so as to obtain the minimum possible activity whilst avoiding an overestimation of international units values, especially those of potential industrial application.

RESULTS

Table 1 shows that, out of all the 58 dry, hot region microbial collections, 48.3% of the microorgnisms produced laccase actvity in units per ml ranging from very low (0.0005) to very high (19.5), depending on the species and strain of the microorganism. Lignin peroxidase production was recorded in 70.7% of the microorganism with the lowest activities at 0.0004 units per ml and the highest at 0.216 units per ml. Xylanase activity was in 100% of the microorganisms with the lowest at 0.15U/ml and the highest at 2.0U/ml. Manganese peroxidase production was apparent in 24% of the microorganisms, the lowest at 0.0435 U/ml and the highest at 1.9 U/ml. Cellulase production appeared in 98.3% of the samples with the lowest at 0.018 U/ml and the highest at 0.255 U/ml.

Table 1. Enzyme activities (Mean of duplicate values) of dry, hot region's fungal collections from mostly *Mopani, Msasa, Mukwa, Muunga* and *Muvanga* indeginous trees, these being physiologically very hard woods inhabiting the Chirundu and the Zambezi valley regions

Name	Isolate no.	Laccase Units/ml	LP Units/ml	XYL Units/ml	MP Units/ml	CEL Units/ml
Antrodia	7A	0	0.0312	0.210	0.0435	0.1425
Bjekandera adusta	25	0	0.0008	1.6655	0.2120	0.090
Coltricia perenis	8	19.5	0.216	0.2425	0	0.141
Coriolopsis sp	3A	0	0.1436	0.25	0	0.018
Coriolopsis sp	4A	0.0065	0.0356	0.265	0	0.081
Coriolospis/ T.cervina	9	0	0.1136	0.2235	0	0.1305
Coriolopsis sp	14A	0.0305	0	0.210	0.0435	0.1425
Coriolopsis sp	23	0	0.0004	2.0	0	0.1335
Coriolopsis sp	35	0	0.0052	1.8060	0	0.1725
Coriolopsis sp	37	0	0	0.6630	0.630	0.1755
Ganoderma lucidium	7	0.0020	0.0484	0.4980	0.125	0.1125
G. lucidium	19A	0.0015	0.060	0.1525	0	0.1365
Hexagonia sp	20A	0.0070	0.1072	0.3480	0	0.1005
Hexagonia sp	26	0	0.0008	1.4680	1.0620	0.1305
Hexagonia sp	32	0.0005	0.0044	1.9565	0	0
Hexagonia sp	42	0.0015	0.0008	2.0	0	0.255
Hexagonia sp	43	0.0105	0.0068	1.4360	1.9545	0.2595
Laetiporus sulphurus	18A	0	0	0.6340	0	0.245
Microporus sp	40	0	0.0032	1.2110	0	0.1905
Microporus sp	44	0	0	1.9565	0.7420	0.2790
Phellinus gilvus	10A	0.0015	0.1296	0.295	0	0.033
Phellinus gilvus	16A	0.0045	0.1404	0.165	0	0.141
Phellinus gilvus	17A	0	0.1268	0.170	0	0.0795
Phellinus ramosus	10	0.0105	0.008	0.9225	0	0.1005
Phellinus sp	46	0.0090	0.0048	1.9565	0.4460	0.230
Polyporus brasiliensis	22	0.0015	0.0212	1.2330	0	0.168
Polyporus brasiliensis	36	0.0115	0	1.6075	0	0.1275
Pycnoporus sanguineus	30	3.610	0	2.0	0	0.1365
Schizopora flavipora	5	0.0015	0	0.470	0	0.1290
Stereum hirsitum	12A	0.0005	0.0388	0.370	0	0.0855
Stereum hirsitum	13A	0	0.0144	0.1930	0.620	0.0795
Trametes cingulata	2	0.0005	0.0064	0.15	0	0.1425
Trametes cingulata	9A	0.0065	0.1000	0.2925	0.4125	0.15
Trametes cingulata	14	0.0005	0.04	0.3630	0	0.087
Trametes cingulata	45	0.0010	0	1.4570	0	0.1785
Trametes elegans	1	0	0.0232	0.30	0	0.0525
Trametes elegans	11A	0	0.0028	0.3065	0	0.0975
Trametes elegans	39	0	0.0012	1.3685	0.5865	0.1275
Trametes leonina	15A	0.0005	0.1564	0.280	0.9580	0.0915
Wrightoporic sp	34	0.0025	0.0024	1.4800	0	0.141
Unknown	3	0	0.0536	0.355	0	0.1245
Unkown	4	0	0.0136	1.805	0	0.099
Unknown	6	0.0165	0.0420	0.540	0	0.0945
Unknown	11	0	0	0.930	0	0.0825
Unknown	13	0	0.048	0.9340	0	0.1155
Unknown	24	0	0.0052	0.9750	0	0.132
Unknown	27	0	0.0048	0.5320	0	0.09
Unknown	28	0.0075	0	1.9565	0	0.0675
Unknown	29	0	0.008	1.6806	1.6785	0.1365
Unknown	33	0.0830	0.0056	1.6555	0	0.0435
Unknown	38	0	0.100	1.9565	0	0.1935
Unknown	41	1.1545	0	2.0	0	0.0345

Table 2 shows the enzyme activities in the 32 presumptive thermophiles that were isolated from the hot water springs at the 5 different high temperatures of between 65 ^{0}C and 100 ^{0}C. Out of these isolates, 34.3% produced laccase, with the lowest activity at 0.0005 units per ml and the highest at 0.025 units per ml. A group of 78.1% produced lignin peroxidase, the lowest being 0.0008 and the highest 0.1564 units per ml. A total 100% produced xylanase, the lowest 0.771 and the highest 2.0 units per ml, 28.1% produced manganese peroxidase, the lowest 0.017 and the highest 1.343 units per ml and 78.1% produced cellulase, the lowest 0.0345 and the highest 0.7215.

Table 2. Enzyme activities (Mean of duplicate values) of presumptive thermophiles isolated from Zimbabwean hot spring water samples

Name/Temperature.	Isolate no.	Laccase Units/ml	LP Units/ml	XYL Units/ml	MP Units/ml	CEL Units/ml
MBLH100exmph 5	50	0	0.0016	1.6555	0	0.2415
MBRC75exmph	52	0	0.0064	2.0	0	0.1230
MBLH100exmph2	54	0	0	1.9565	0	0.0990
MBLH100exmph1	55	0.0005	0	2.0	0	0
MBLH100exmph4	61	0.0015	0.0056	4.44	0	0
MBLH100exmph5A	62	0.0005	0.0056	1.5675	0	0.096
MBLH100exmph6	68	0.0005	0.0016	2.0	0	0.7215
MBLH100exmph9	73	0	0	1.5675	2.4510	0.1155
MBLH100exmph3	75	0.0235	0	2.0	0	0.04 5
MBLH100exmph3	76	0.0005	0	2.0	0	0.1425
MBLH100exmph8	79	0	0.0032	2.0	0	0.0255
MBLH100exmph10	80	0	0.0136	2.0	0.0245	0
MBLH100exmph7	85	0	0.0016	2.0	0	0.0855
CHRND40	66	0.0005	0	1.607	0.0170	0.1335
MBRD75exmph	58	0	0	2.0	0.2795	0.0585
MBRD80exmph1	65	0	0.0036	1.95	0	0.0915
MBRD80exmph5	70	0	0.1564	1.4570	0	0
MBRD80exmph4	72	0	0.0404	1.480	0	0.0645
MBRD80exmph3	74	0	0.0060	2.0	0	0.0855
MBRD80exmph1A	78	0.0005	0.0028	2.0	0	0.0037
MBRD80exmph23	82	0.0005	0.0056	1.8060	0	0.096
MBRD75exmph3	84	0	0.0032	2.0	1.503	0.078
NHTZTS70exmph2	71	0	0.0008	1.957	0	0.0345
NHTZTS70exmph3	70	0	0.0028	2.0	0.1430	0
TSPS80exmph3	67	0	0.0148	1.5340	0	0.0105
TSPS80exmph3A	69	0	0.0024	2.0	0	0
TSPS80exmph4	81	0	0.0048	2.0	0.2540	0.0405
TSPS80exmph2	87	0	0.0072	1.505	0	0.0585
TSPS80exmph5	88	0	0.0024	2.0	0	0
RUP65XYL4.5bm1	56	0.0005	0.0024	0.7710	1.0690	0.0405
XYL65ALK9.3wm1	57	0.0195	0.004	1.2490	0	0.036
RUP65XYL9.3wm	59	0.0030	0.0008	0.8645	1.3430	0.1005

Exmph= Thermophillic isolate,
MBLH100, MBLH80,MBRC80, MBRD75 or 80, NHTZTS70, RUP65 & TSPS80 = Names & temperature of hot springs from which the microorganisms were isolated.

The total 134 wet region fungal collections are named and listed in table 3 shown below. Screening for enzyme activity showed that 31.3 % of them produced laccase with the lowest recording an of activity at 0.00001 and the highest recording 0.0644 U/ml. Lignin peroxidase was produced by 26.9% of microrganisms, with the lowest at 0.000004 and the highest 0.00227 U/ml. Xylanase production was made by 99.2% of the wet season collections, the lowest at 1.4 units/ml and the highest recording above 20 U/ml. Manganese proxidase was produced by 81.3% of the collections, lowest 0.000011 and the highest 0.0038U/ml and 31.3% produced cellulase, the lowest at 0.015, the highest 4.455 U/ml.

Table 3. Enzyme activities (Mean of duplicate values) of the wet and humid regions' fungal collections from mostly exotic *Eucalyptus, Pine* and *Wattle* plantations and indeginous, physiologically soft woods of Chimanimani, Bvumba, Mutare and Bhema valley regions of Zimbabwe

Name	Isolate no.	Laccase Units/ml	LP Units/ml	XYL Units/ml	MP Units/ml	CEL Units/ml
Amanita pantherina	0414Z	0	0	10.95	0.0038	0
A.pantherina	0460Z	0	0.002232	2.2	0.000475	0
Amonita sp	0457Z	0	0.000524	20+	0	0
Auricula sp	0433Z	0	0.000308	2.85	0.00037	0.585
Auricularia/ Aur. judae	0485Z	0	0.000068	20+	0.00027	0
Collybia distorta	0444Z	0	0	20+	0.000335	0
Collybia distorta	0448Z	0	0	5.725	0	0.36
Collybia distorta	0499Z	0.064445	0.000304	2.61	0.0004	0
Coprinus micacues	0412Z	0	0.000188	20+	0.000745	3.135
Coprinus micaceus	0428Z	0	0	4.77	0.001305	1.1805
Coprinus micaceus	0530BC/Z	0	0.0001	2.25	0.000815	0
Coriolopsis polyzona	0423Z	0	0	2.165	0.00011	0
Coriolopsis poyzona	0431Z	0.00018	0	2.96	0.001765	0
Coriolopsis polyzona	0442Z	0	0	1.4	0.00007	0
Coriolopsis polyzona	0475Z	0.000015	0.000216	20+	0.0002	0
Coriolopsis polyzona	0511Z	0	0.000004	20+	0	0.045
Coriolopsis polyzona	0528Z	0.00041	0.000168	20+	0.000385	0
Coriolopsis sp	0517Z	0	0	20+	0	0
Coriolus hirsitus	0403Z	0	0	2.24	0.000185	0.0015
Coriolus hirsitus	0477Z	0	0.000004	4.945	0.000445	0
Coriolus hirsitus	0514Z	0.00095	0	20+	0.00045	0
Coriolus versicolor	0446Z	0.00106	0	20+	0.000125	0
Coriolus versicolor	0447Z	0.0095	0	13.115	0.001445	0
Creoidotus mollis	0432Z	0.000055	0	1.77	0.001135	0.675
Crepidetus mollis	0480Z	0.000030	0	14.14	0.000515	0
Crepidetus sp	0505Z	0	0	20+	0.000725	0
Cyptotrama asprata	0491Z	0	0.000088	20+	0.00069	0
Daldina concentrica	0529Z	0	0.000004	20+	0.000875	0
Ganoderma applanatum	0413Z	0	0.000548	20+	0	2.685
G.applanatum	0470Z	0	0	6.86	0	0
G.applanatum	0487Z	0	0	4.475	0.00056	0
G.applanatum	0497Z	0	0	5.2	0.00053	0
G.lucidium	0509Z	0	0	4.4	0.00052	0
G.lucidium	0510Z	0.00075	0.000044	10.875	0	0
G.lucidium	0518Z	0	0	11.49	0.00041	0
G.lucidium	0531Z	0.00071	0	20+	0.0008	0
Ganoderma sp	0461Z	0	0	12.02	0	0
Glocophyllum separium	0455Z		0	0	0.000405	0
Hexagonia tenius	0525Z	0	0	3.4	0.00003	0
Hypoloma fasciculare	0481Z	0	0	4.85	0.000585	0
H.fasciculare	0489Z	0	0	4.9	0.00105	0.39
Laxitetum bicolor	0435Z	0	0	1.855	0.00009	0
Laxitetum bicolor	0451Z	0.000275	0	1.74	0.00069	0
Lignocus sacer	0417Z	0	0.000036	12.775	0.000195	0.27
Lignosus sacer	0464Z	0.000325	0	3.0	0.0002	0
Lignosus sacer	0469Z	0.00021	0.000408	9.4	0.00047	0.285
Lenzites elegans	0436Z	0	0	20+	0.00075	0
Odontia sp	0462Z	0	0	1.79	0.000515	4.455
Odontia sp	0468Z	0.00013	0	2.61	0.000895	0
Odontia sp	0474Z	0	0	20+	0.000915	0
Odontia sp	0519Z	0	0	20+	0	0
Paxillus sp	0501Z	0	0	6.0	0.002195	0
Phellinus concatus	0403Z	0.000135	0	12.325	0.00021	1.575
Phellinus gilvus	0526Z	0.00193	0	20+	0.00035	0
Phellinus sp	0397Z	0	0.000004	20+	0	2.445
*Phellinus*sp	0441Z	0	0	20+	0.00060	0
Phellinus sp	0472Z	0.002255	0	5.515	0.0093	0
Phellinus sp	0476Z	0.00348	0	11.765	0	0
Phellinus sp	0478Z	0	0	2.675	0.002285	0

Table 3. (continued)
LP=Lignin peroxidase, XYL=Xylanase, MP=Manganese peroxidase, CEL=Cellulase

Name	Isolate number	Laccase Units/ml	LP Units/ml	XYL Units/ml	MP Units/ml	CEL Units/ml
Phellinus sp	0482Z	0.000015	0	14.6	0.00016	0
Phellinus sp	0490Z	0.0000465	0	20+	0.000054	0
Phellinus sp	0492Z	0	0	14.545	0.00081	0
Phellinus sp	0498Z	0	0.000052	4.0	0.00060	0
Phellinus sp	0503Z	0	0	20+	0.00064	0
Phellinus sp	0504Z	0.000045	0	2.87	0.00054	0
Phellinus sp	0521Z	0	0	8.34	0.00058	1.545
Phellinus sp	0522Z	0	0	20+	0.00121	0
Phellinus sp	0524Z	0.0000155	0.000264	7.795	0	0
Polyporous Dictyoporuos	0411Z	0	0.000028	8.69	0.000695	2.865
Poria sp	0466Z	0	0	9.52	0.000245	0.054
Poria sp	0513Z	0	0	6.0	0	0.39
Pycnoporus coccineus	0402Z	0	0.001976	20+	0.003125	0.135
P.coccineus	0404Z	0	0	20+	0.003225	0.195
P.coccineus	0452Z	0	0	20+	0	0
P.sanguineus	0454Z	0.00057	0	20+	0	0
Russula capensis	0471Z	0	0	20+	0.00116	0
Russula sororia	0400Z	0.067305	0.000388	2.625	0.00029	0.03
Russula sp	0415Z	0.001025	0	3.23	0	0
Russula sp	0416Z	0.000115	0.00008	20+	0.00092	0.15
Russula sp	0424Z	0	0	20+	0.00117	0
Russula sp	0425Z	0.00652	0	2.76	0	0.315
Schizophyllum commune	0467Z	0	0	20+	0.00045	0
S.commune	0473Z	0	0	11.395	0.000165	0
Stereum hirsitum	0408Z	0	0	5.79	0.000555	0
S.hirsitum	0418Z	0	0	20+	0.001295	0
S.hirsitum	0429Z	0	0	3.005	0.00082	1.29
S.hirsitum	0430Z	0	0	7.3	0.00186	1.335
S.hirsitum	0440Z	0.000185	0	5.45	0.000035	0.165
S.hirsitum	0445Z	0.000635	0.000608	2.505	0.00063	0
S.hirsitum	0449Z	0	0	5.29	0.000495	0
S.hirsitum	0496Z	0	0	20+	0.00078	0
S.hirsitum	0507Z	0	0	13.2	0.00071	0
S.ostrea	0397Z	0	0	4.07	0.00052	2.34
S.ostrea	0407Z	0	0	2.815	0.000135	0
S.otrea	0450Z	0	0	2.925	0.00295	0
S.ostrea	0483Z	0.000045	0	5.835	0.000595	0
S.ostrea	0494Z	0.000060	0.000044	20+	0.00145	0
S.ostrea	0520Z	0.004685	0	20+	0	0
Suillis sp	0419Z	0	0.000104	3.15	0.00003	0.255
Trametes cingulata	0406Z	0	0	7.71	0.000265	1.98
T.cingulata	0453Z	0	0	10.505	0.000185	0
T.cingulata	0527Z	0	0	20+	0	0
T.meyenii	0434Z	0	0	20+	0	0
T,meyenii	0437Z	0.000025	0	3.005	0.000085	0
T.nivosa	0409Z	0	0	20+	0.003222	0.27
Trametes sp	0508Z	0	0	20+	0.00128	0
T.versicolor	0512Z	0.00227	0.000024	4.565	0.00161	0
Tremelia (wa) sp	0516Z	0	0	2.91	0.00242	2.97
Tubaria furfaraceae	0410Z	0	0	13.43	0.000525	2.235
Unkown	0420Z	0	0	3.095	0.000865	0.27
Unknown	0421Z	0	0	10.577	0.000365	0.165
Unknown	0422Z	0	0	4.5	0	0.18
Unknown	0426Z	0	0.0000008	1.915	0.000305	0.24
Unknown	0427Z	0	0.000156	20+	0.00005	1.065
Unknown	0443Z	0	0	1.945	0.000017	0
Unknown	0456Z	0.000215	0	20+	0	0
Unknown	0458Z	0.000025	0	20+	0	0
Unknown	0459Z	0.00033	0	4.115	0.0008	0
Unknown	0463Z	0	0.000148	20+	0.000235	0
Unknown	0465Z	0	0	20+	0	0

Table 3. (continued).
LP=Lignin peroxidase, XYL=Xylanase, MP=Manganese peroxidase, CEL=Cellulase

Name	Isolate no.	Laccase Units/ml	LP Units/ml	XYL Units/ml	M P Units/ml	CEL Units/ml
Unknown	0479Z	0	0	20+	0.00078	0
Unknown	0484Z	0.00001	0	5.84	0.000011	0
Unknown	0486Z	0	0.000168	3.13	0.000121	0.6
Unknown	0488Z	0	0	20+	0.001055	0
Unknown	0493Z	0	0.0001	20+	0.00055	0
Unknown	0495Z	0	0	20+	0.000965	0
Unknown	0500Z	0	0.001048	20+	0	0
Unknown	0449BZ	0	0	20+	0.000405	0
Unknown	0459BZ	0	0.000216	14	0.000395	0
Xylaria sp	0502Z	0	0	2.075	0.000865	0

DISCUSSION

Over 224 white-rot fungi and the hot water spring presumptive thermophiles were collected, isolated, cultured and screened for the enzymes potentially useful in the biodegradation of pulp effluent waste.

The collection of both dry season and wet season fungal samples provides for a wider bio diversity of the gene pool of industrial enzymes and so does the successful isolation and screening of the presumptive thermophiles from the hot water springs.

The discovery of presumptive thermophiles has the potential to produce effluent waste biodegrading enzymes that withstand the high industrial temperature operating conditions.

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Assessment of the major water and nutrient flows in the Chivero catchment area, Zimbabwe

Innocent NHAPI[1], Zvikomborero HOKO[2], Maarten A. SIEBEL[3] and Huub J. GIJZEN[3]

[1] Department of Civil Engineering, University of Zimbabwe, Box MP167, Mt Pleasant, Harare, Zimbabwe
[2] Department of Works, City of Harare, Box 1583, Harare, Zimbabwe
[3] IHE Delft, P.O. Box 3015, 2601 DA Delft, The Netherlands

[1]inh@ihe.nl

***ABSTRACT*:**
The management of water resources is best done on an integrated catchment basis; taking into account the impact of pollution on available water quantity and quality. A study was done from June 2000 to March 2001 in Harare, Zimbabwe, to establish major water and nutrient flows in the Chivero sub-catchment area. Lake Chivero is part of the major water supply source for Harare and is located downstream. Discharges from sewage treatment works, urban and rural agriculture, and industries, have caused a severe stress on water quality of the eutrophic lake. The study quantified major water flows through gauging stations on rivers, current metering, and hydrological modelling. Flows for raw water abstractions, sewage and water treatment works were obtained from continuous metering and pumping readings. Water samples were collected monthly for sewage, rivers and Lake Chivero, and analysed according to standard methods. Water and nutrient balances were developed. The results showed that urban water demand would exceed available treatment capacity by the year 2003. Sewage effluent presently is the major source of nutrients in the rivers. The absence of adequate flushing of the Lake gives rise to accumulation of the nutrients in the Lake. It was concluded that the current situation is not sustainable. It was recommended that the next water supply source be found outside the catchment so that its water can help flush the Lake, and that sewage be treated to higher standards (without any pasture irrigation) and discharged directly into the rivers for recycling. The other alternative is to recycle the nutrients in controlled urban agriculture, thereby reducing fertiliser runoff. Stricter regulations and regular monitoring was recommended to control industrial pollution.

Keywords*:wastewater; pollution; eutrophication; nutrients; mass balances; Lake Chivero*

1. INTRODUCTION

1.1 Water Scarcity

Despite recent good rain seasons, Zimbabwe is generally a water scarce area. Zimbabwe has faced periodic drought periods in the recent past with six drought seasons from 1980 to 1997 (Bailey *et al*, 1996; World Bank, 1998). Almost the whole of Zimbabwe is more than 300 m above mean sea level and 675 mm is generally taken as the average annual rainfall for the whole country (Hoko, 1999). Fresh water is a limited resource and its demand will continue to increase due to population growth, increased irrigation requirements and industrialisation. The current population of Zimbabwe is about 12 000 000 covering a total area of 390 580 km^2. Assuming that 8 – 10% of the annual rainfall appears as river flow (Hoko, 1999), the available renewable fresh water resources per capita is 1 980 m^3/cap.yr. With an annual population growth of about 3.5% (WB, 1998), this figure will drop to about 840 m^3/cap.yr by the year 2025. According to a criteria for renewable fresh water needs per capita per year by Gardner-Outlaw and Engelman (1997), and Engelman and LeRoy (1993), the country will start experiencing chronic water scarcity problems. Presently about 2 000km^2 (4.5% of arable land (World Bank, 1998)) are on irrigation. A rational water management system is therefore a priority in the area.

1.2 Pollution

Eutrophication of major water bodies, especially Lake Chivero, is now becoming a problem in Zimbabwe. Spellman (1996) defines eutrophication as the natural ageing of a lake or land-locked body of water, which results in organic material being produced in abundance due to a ready supply of nutrients accumulated over the years. Self-purification has to be sustained to reduce downstream water quality deterioration. This self-purification process is very efficient and the stream will suffer no permanent damage as long as the quantity of waste is not too high (Spellman,

1996). An understanding of this self-purification process is therefore important to prevent overloading the stream ecosystem. The degree of pollution and the character of the stream determine the amount of time the self-purification process will take.
Water hyacinth (*Eichhornia crassipes*) and algae proliferation in Lake Chivero, the capital city of Harare' major water supply source, can be attributed to nutrients introduced by direct discharge of treated sewage effluent into the inflow rivers (Jarvis *et al*, 1982; Mathuthu *et al*, 1997). The decay of the overgrowth and its decomposition are processes that consume the DO of the river and can deplete it to levels far below the critical levels needed to sustain life of higher order aquatic animals such as fish. Moreover, some of the aquatic plants are widely reported as poisonous to some of the fish and livestock (Mathuthu *et al*, 1997). From 1960 eutrophication has been evidenced by dense blooms of blue-green algae, principally *Microcystis aeruginosa* and *Anabaema sp*. (Thornton, 1982). By 1968, nitrogen and phosphorous concentrations in the Lake had increased by a factor of between 5 and 10 their original levels, and nitrogen became the primary growth-limiting nutrient (Thornton and Nduku, 1982; Watts, 1982).

1.3 Cost Implications

Urban councils are the water authorities in Zimbabwe and are also responsible for sanitation (Urban Councils Act Chapter 29.15). They are now faced with enormous costs associated with treating increasingly polluted water and also treating wastewater to very strict effluent standards (Zimbabwe Government S.I. 274 of 2000). This will resulted in increased tariffs to users who are already faced with an ailing economy; abnormally high inflation, escalating prices and soaring unemployment rates. Table 1 gives an overview of recent sewage treatment projects constructed under a World Bank-funded scheme. Cost recovery tariffs would consume an excess of 20% of household incomes. Literature figures are 5% for water and sanitation given by Franceys (1999) and 3% for sanitation only given by Franceys *et al* (1992), Cairncross (1992) and Cairncross and Feachem (1983). The marginal cost of providing additional water supply and wastewater treatment infrastructure is rising considerably. The increasing costs of effluent treatment provide an incentive for the reduction of volume and concentration of wastewater.

Table 1: Overview of STWs constructed under the Urban II Programme (Source: PCMU database, Min. of Local Government)

Item	SAST 2, Bulawayo	KweKwe	Masvingo	Hatcliffe, Harare	Redcliff	Gwanda	Marondera	Karoi	Gimboki, Mutare
Trickling filter						X			
BNR works	X	X	X	X	X		X		X
WSP								X	
Power supply	X		X			X	x		X
Raw sewage pumping						X			
Effluent irrigation				X		X		X	X
Sludge irrigation			X						X
Capacity, m^3/d	15 000	5 000	13 500	2 500	2 000	2 300	4 500	1 700	32 000
Hydraulic loading, lcd			100				160		120
Contract cost, Z$1m	66.68	17.349	26.561	18.718	43.71	24.646	69.496	7.961	108.683
Project period	5/96 – 2/99	1/97– 2/99	4/96-1/98	9/96-12/98	5/97-4/00	7/96-3/98	8/99-4/00	7/98-11/99	1/99-8/00
Population served	50 00	40 00	100 000	20 000	17 500	20 000	50 00	62 100	266 000
Exchange rate at end of project period	38.1	38.1	18.797	18.797	38.1	18.797	38.1	38.1	38.1
Cost/m^3, Z$	4 112	3 470	1 967	7 487	21 855	10 516	15 444	4 683	3 396
Cost/capita, Z$	1 234	434	266	936	2 498	1 232	1 190	128	408
Cost/capita, US$	37.38	16.38	14.13	49.79	65.55	65.56	36.48	3.36	10.72
Comments	Ext./new unit	Ext./new unit	Ext./new unit	New works	Ext./new unit	New works	New works	New works	Ext./new unit

1.4 Research Focus

A study was conducted from June 2000 to March 2001 aimed at assessing the environmental sustainability of the current water management system in the Chivero catchment. The major issue was water quality, especially sewage effluent and other discharges into Lake Chivero. This was achieved by quantifying the major water and nutrient flows and an assessment of the interaction of water and nutrients leading to deterioration of water quality in the Lake. This study was part of a broader research on the integrated water resources management of the Lake Chivero basin.

2. MATERIALS AND METHODS

2.1 Study Area

The study area is defined as the Lake Chivero catchment (Figure 1). The total catchment area is 2 136 km^2 (JICA, 1996), consisting of approximately 10% urban development and 90% rural. The latter comprises communal and commercial farming lands in nearly equal proportions (Magadza, 1997a). Lake Chivero basin is also part of the Manyame catchment. The Lake was created in 1952 (Marshall, 1997). Other dams in the catchment are Seke Dam (constructed in 1929 with maximum surface area 110 ha) and Harava Dam (constructed 1972 with maximum surface area 215 ha). Lake Chivero has a surface area of 26.449 km^2 at full capacity and a mean depth of 9.3 m (from Department of Water records). It receives its waters from the following major rivers: Manyame, Mukuvisi and Marimba. Ruwa and Nyatsime Rivers also feed into Manyame River and they drain Ruwa and Chitungwiza respectively. The catchment area of Mukuvisi and Marimba rivers is the City of Harare. The average annual precipitation in Harare is 830 mm (ranging 445 – 1 246 mm) with most received as high intensity storms in October to April (JICA, 1996; Nyamangara and Mzezewa, 1999). The mean annual runoff in Harare is about 140 mm (Department of Water, 1995).

Harare obtains its water from a number of dams on the Manyame River and its tributaries: namely Seke Dam (capacity 3 380 Ml), Cleveland Dam (910 Ml), Lake Manyame (480 236 Ml), Lake Chivero (247 181 Ml) and Harava Dam (9 026 Ml) (JICA, 1996; McKendrick, 1982). Of these dams, Chivero and Manyame are the main sources of water supply to the city. The last population census in Zimbabwe was in 1992 and estimate figures are given in Table 2 below.

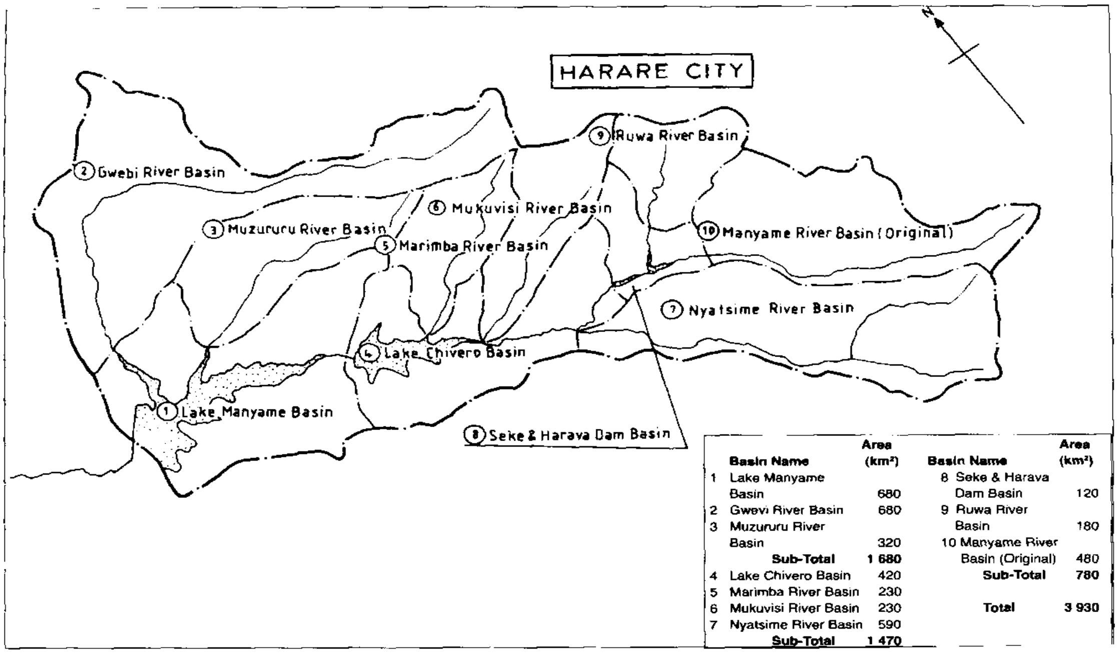

Figure 1: Upper Manyame Basin including Lake Chivero Catchment (Source: Jarawaza, 1997)

Table 2: Population of the Urban Areas of the Chivero Catchment (Source: JICA, 1996; Magadza, 1997; Taylor and Mudege, 1997; Zimbabwe Factbook, 1998)

Urban Area	Area, (km)^2	1969	1982	1992	2001*
Harare City	447.1	386 000	658 000	1 189 103	2 009 000
Chitungwiza	42.0	15 000	172 000	274 912	465 000
Epworth Local Board	11.1			62 630	106 000
Ruwa Local Board	31.4	-	-	1 447	20 000**
Total	531.6	401 000	830 000	1 548 092	2 600 000
% of National	0.14	8	11	15	22

* Estimated using 6% growth from Taylor and Mudege (1997)
** Estimate for rapidly growing town closer to Harare

2.2 Data Collection and Analysis

The study focused on total nitrogen (TN), total phosphorus (TP) and flows. Monthly river samples were collected and analysed according to standard methods (APHA/AWWA/WCPF, 1992). Samples were also collected from Crowborough and Firle sewage treatment works (STW) and Lake Chivero on a monthly basis. Samples were collected in polythene containers which had been washed with phosphorous – free detergents, rinsed with distilled water and left to stand overnight in 1 M HCL. They were rinsed again with distilled water and twice with sample water on site. Phosphorous was digested with concentrated sulphuric and nitric acids and the phosphate content determined by the vanado molybdophosphoric acid method. Nitrate was determined using the electrode screening method (WTW Microprocessor pH/ion meter pMX 300). TKN samples were digested according to the micro-Kjeldahl method and ammonia collected in excess boric acid and determined by titration with 0.02 M sulphuric acid. Flows were obtained from gauging stations data as kept by the Department of Water Development (DWD) and the City of Harare. The sampling locations are shown in Figure 2. Further data were gathered from literature. Extensive use was also made of the JICA Report of 1996, which dealt with major pollution issues in the catchment.

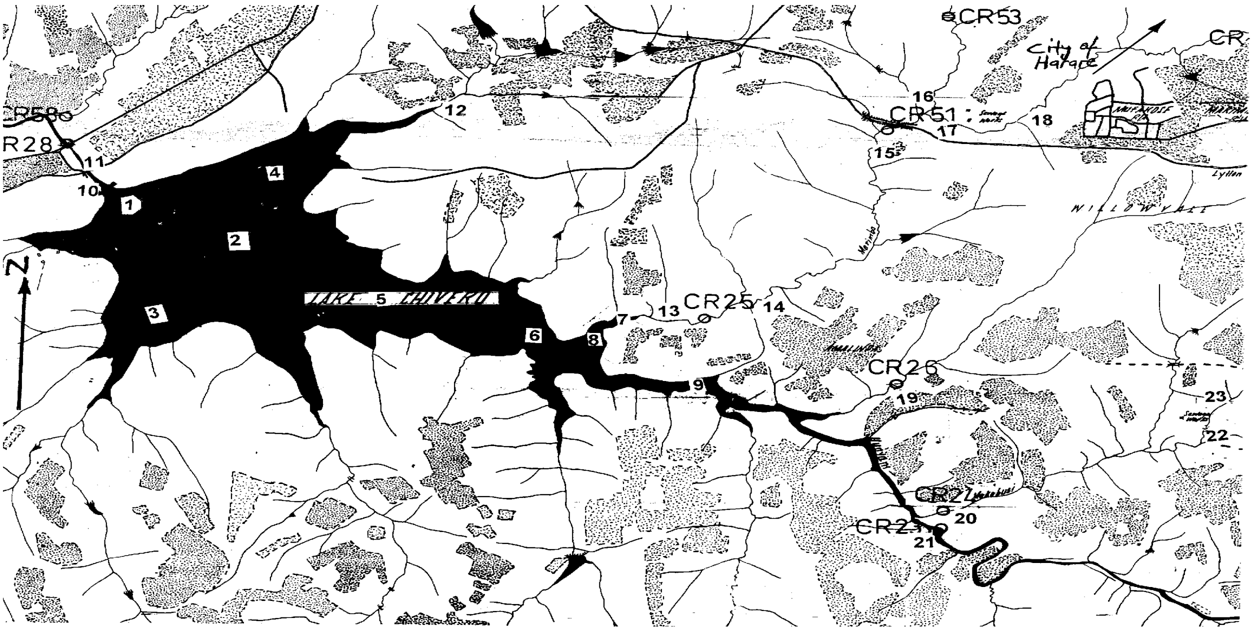

Figure 2: Site Map for the Study Area and Sampling Locations (Source: DWD)

3. WATER RESOURCES

3.1 Water Supply

The Prince Edward and Morton Jaffray Water Treatment Works (WTW) supply the study area and have production capacities of 90 000 m^3/d and 614 000 m^3/d, respectively (JICA, 1996). However, actual respective productions are around 23 000 m^3/d and 350 000 m^3/d respectively. Treatment processes consist of sludge blanket type clarifier, rapid sand filtration, and chlorination. The generated wastewater is either discharged into the river through a retention tank or pumped to farmland for irrigation use. Wastage at WTWs can be as high as 12% for Prince Edward and 26% for Morton Jaffray (JICA, 1996). These high values are due to frequent backwashing and the high dosage of coagulant due to deteriorated water quality and increased algae in the raw water. Water abstraction figures for Morton Jaffray WTWs for 1982 to 2000 were as shown below. The abstractions are fast approaching the 600 000m^3/d capacity of the plant. This means an extra capacity will be required by year 2003 if the wastage was not included in the design of the plant. If this was done then this timing is pushed beyond 2010.

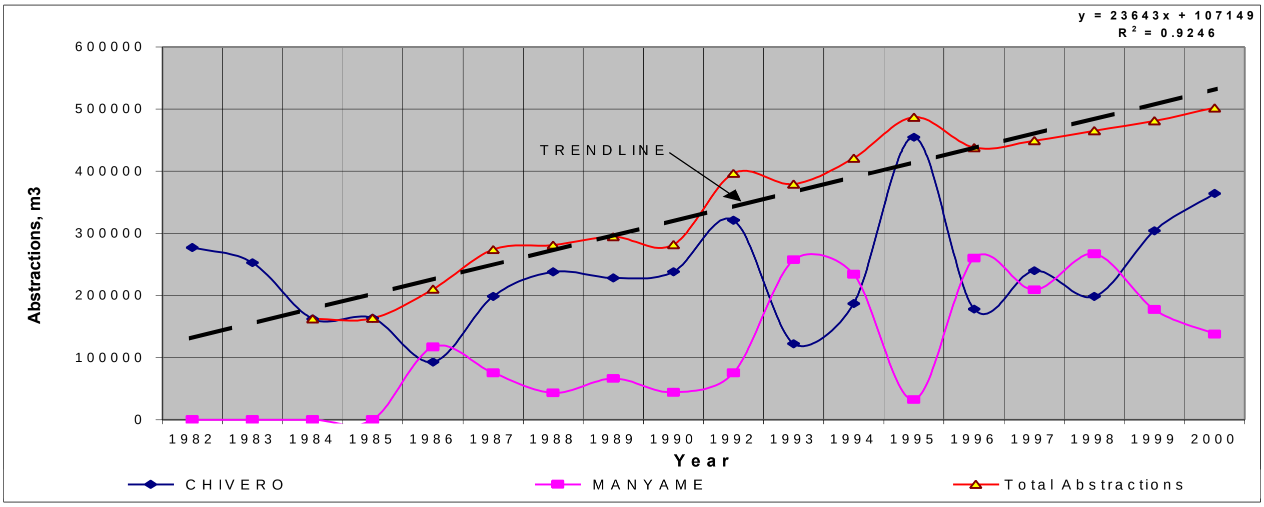

Figure 3: Trends in daily abstractions at Morton Jaffray STWs (Source: City of Harare database)

3.2 Sewage Treatment

Table 3 summarises information on the existing sewage treatment infrastructure.

Table 3: Existing Sewage Treatment Works in the greater Harare Area (Source: JICA, 1996; PCMU)

Plant	Area Served and Population	Treatment System	Design Capacity m^3/d	Present Influent Flow m^3/d	Discharged to River, m^3/d	Irrigation Use, m^3/d	Construction Time
Crowborough	686 000	TF	36 000	74 000	**11 600**	**62 400**	**Unit 1 1957** **Unit 2 1957**
		BNR	18 000	18 000	18 000		Unit 3 1970s
		BNR	54 000	55 311			Unit 4 1996 pending
Firle	946 000	TF	36 000	44 000		44 000	Unit 1 1960 Unit 2 1970s
		BNR	36 000	36 000	11 500	24 500	Unit 3 1979-1981
							Unit 4 1986-1996
		BNR	(72 000)	72 000	72 000		Unit 5 (I) 1994-1996 Unit 5 (II) 1994-1996
Malborough	15 000	WSP	2 000	2 000		2 000	
Donnybrook	134 000						
Block 1		WSP	unknown	400			
Block 2		WSP	unknown	1 350			
Block 3		WSP	unknown	1 400			
Block 4		WSP	unknown	2 350			
		TOTAL	5 500	5 500	?	5 500	Overloaded, no flow records
Hatcliffe*	34 000	Extended Aeration	2 500	2 500	2 500		
Zengeza, Chitungwiza	465 000	BNR	20 000	20 000	20 000		Commissioned in 2000
Ruwa	20 000	WSP	5 300	5 300		5 300	Commissioned 1993
Total flows			**233 300**	**279 300**			

* The effluent from Hatcliffe STW is discharged into the Manyame catchment
** Records and design criteria can indicate discharge to farms but operational problems would result in river discharges
Sludge Flows have been ignored

The major plants in Harare are now overloaded. The total design capacity of the plants in Table 3 is 233 300 m^{3}/d compared to total current flows of about 279 300. This will have serious implications for downstream water quality. Flow readings from City of Harare do not balance for each treatment plant. Where influent and pumping records are available, these were assumed correct and the discharge to the river estimated as the balance. Sludge volumes were not directly included in the calculations although they are in-built in pumping figures. Chitungwiza recently commissioned a new BNR system and they have been sending their effluent out of the catchment for irrigation on Imbwa Farm. Hatcliffe plant discharges out of the catchment area under review.

3.3 Rainfall and Runoff

The rainfall pattern for the Chivero pattern varies a lot in time and in space. Figure 4 represents the rainfall at some Harare stations. The pattern shows that recent years have generally received good rains. The resultant flows at the three main gauging stations just before Lake Chivero are shown in Fig 5. Station C21 is on Manyame, C22 on Mukuvisi, and C24 on Marimba River. C22 and C24 had fairly similar flow patterns and have the same magnitude. These two stations measure flows from Harare urban and have catchment areas of 231 km^2 and 189 km^2 respectively. A mean area runoff of 535 mm is obtained compared to normal values of about 140 mm given by the Department of Water (1995). This points to the influence of water recycling through Lake Chivero.

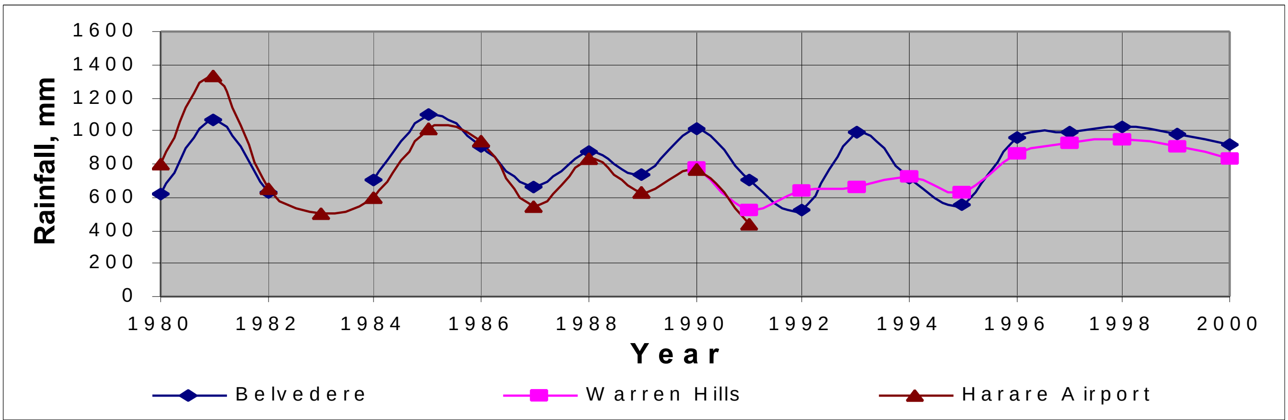

Figure 4: Rainfall patterns at Belvedere, Warren Hills, and Airport stations for the period from 1980

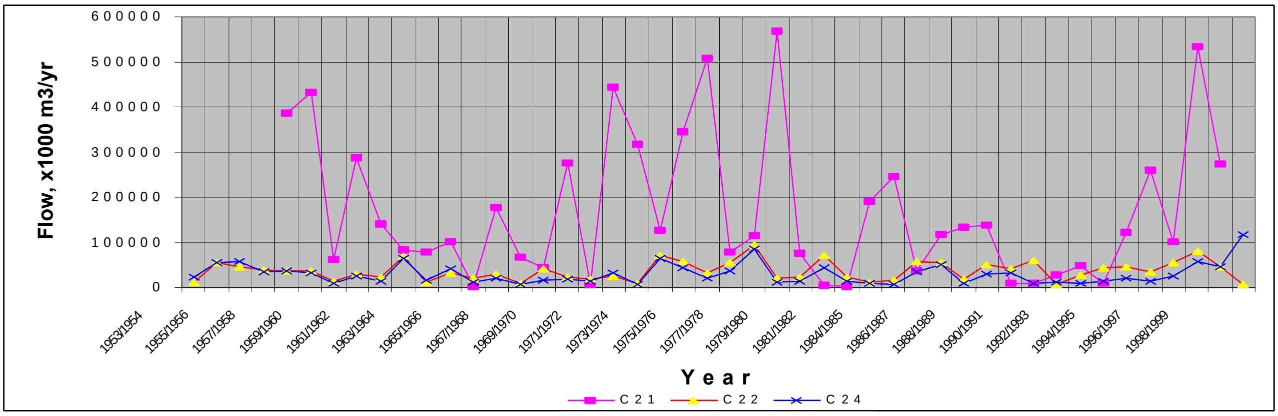

Figure 5: Annual flows at three main gauging stations before Lake Chivero

3.4 Water Balance

A water balance for Lake Chivero was developed based on average flow data from 1990 as shown in Table 4. Direct area runoff was determined from the catchment area in Fig 1 and assuming about 8 – 10% of rainfall as runoff (Zimbabwe Factbook, 1998). Precipitation was considered over the entire Lake surface area assuming no losses. The discrepancy in the balance is attributed to groundwater movements, and errors of estimation and measurement. It was found that 15% of annual flows in Marimba, Manyame and Mukuvisi River occur in the May to November dry season. The retention time of the Lake based on Table 4 is 346 days, pointing to inadequate flushing of the nutrients. Retention times of less than 6 months are desirable (Thornton, 1980). Out of the 235 000 m^3/d raw water abstracted from Lake Chivero, about 136 000 m^3/d (58%) is returned as sewage effluent to the lake.

Table 4: Water balance for Lake Chivero based on 10-year data from 1990 (Data source: DWD, City of Harare)

Item	Gauging Station	Flow, m^3/year
INFLOW		
Manyame River	C21	153437333
Marimba River	C24	32811700
Mukuvisi River	C22	40745600
Precipitation over the Lake	Belvedere, annual 786 mm	20793939
Direct area runoff		13207992
Total Inflow		**260996565**
OUTFLOW		
Lake spillway	C17	90029900
Raw water abstraction	City of Harare	95182143
Evaporation	E-pan, DWD	42688686
Total outflow		**227900729**
inflow - outflow		33095835
Discrepancy as % of inflow		**12.7%**

4. WATER QUALITY

4.1 Sewage and River Nutrient Levels

Nutrient concentrations at the major sewage treatment plants in Harare are shown in Tables 5 and 6 below. The influent phosphorus concentrations were persistently very low. The BNR effluent at CSTW exceeded the limit of 10 mg/l only once during the study period. The results for 18 – 17U on Marimba River and R1 – 16 on Little Marimba reveal an influence of pasture irrigation on these two river stretches. Downstream of sewage discharge, nitrogen seemed to have a higher impact on Marimba River with a small amount of TN lost to the river between points 15 and 13; a stretch of about 8 km. Stations 20, 22, 23, holding pond (E1), trickling filter (E4) and BNR discharges into Mukuvisi River were also monitored (Table 6). BNR and holding pond effluents had lower phosphorus concentrations than the upstream river. The river pollution could be due to industrial effluents. There seemed to be no significant nitrogen and phosphorus reduction from the point of effluent discharge (22) to the river entrance into Lake Chivero (20). Manyame River (21) had higher concentrations than previously reported by JICA (1996). This could be due to sewer overflows in Chitungwiza and the release of waste stabilisation pond effluent into rivers at Donnybrook and Ruwa plants.

Table 5: Summary results of nutrient levels at Crowborough STW and Marimba River

Description	Station	# of Samples	TN, mg/l		TP, mg/l	
			Mean	StDev	Mean	StDev
Influent, domestic + industrial	C Infl	10	***23.48***	*13.03*	***2.11***	*1.01*
BNR Effluent, 17E	17E	10	***4.28***	*3.53*	***0.26***	*0.10*
Pond Effluent 2	Pond 2	10	***52.74***	*62.54*	***2.54***	*1.46*
Pond Effluent to Pastures	Pond 1	10	***33.31***	*28.81*	***2.38***	*1.49*
Upstream of Pond Discharge	17U	10	***314.14***	*414.39*	***0.38***	*0.06*
Digested Sludge	CDS	10	***939.67***	*783.23*	***49.75***	*17.14*
Upstream of STW	18	10	***7.88***	*5.74*	***0.33***	*0.12*
Little Marimba, before Marimba	16	10	***68.47***	*113.89*	***0.54***	*0.82*
Upstream, Little Marimba	R1	10	***2.90***	*2.28*	***0.26***	*0.08*
After confluence of Marimba and Little Marimba rivers	15	10	***14.56***	*7.43*	***1.46***	*1.20*
Marimba River entrance into Lake Chivero	13	10	***13.8***	*6.6*	***1.0***	*0.5*

Table 6: Summary results of nutrient levels at Firle STW and Mukuvisi and Manyame Rivers

Description	Station	# of Samples	TN, mg/l		TP, mg/l	
			Mean	StDev	Mean	StDev
100 m upstream of sewage discharge point	Firle B	10	***8.9***	*11.2*	***7.4***	*15.3*
Raw sewage	Firle Raw	10	***32.9***	*15.9*	***2.8***	*0.6*
Trickling filter/pond effluent pumped to pastures	E1	10	***28.0***	*12.5*	***1.7***	*0.9*
BNR effluent	E2	10	***15.4***	*13.5*	***0.2***	*0.1*
About 100 m after last sewage discharge points	E3	10	***8.2***	*8.4*	***0.5***	*0.2*
Trickling filter effluent discharged into the river	E4	10	***25.6***	*35.5*	***2.8***	*4.6*
Digested sludge ready for pumping to pastures	Firle DS	10	***969.4***	*790.9*	***40.0***	*17.5*
Marimba River entrance into Lake Chivero	20	10	***8.1***	*5.9*	***0.6***	*0.4*
Manyame River entrance into Lake Chivero	21	10	***4.2***	*3.9*	***0.2***	*0.1*
Small stream originating from industrial areas	19	10	***39.4***	*46.3*	***2.4***	*1.4*

The results showed that Manyame contributes the highest hydraulic load whilst Marimba River contributed most in terms on nitrogen and phosphorus loads to Lake Chivero (Fig 6).

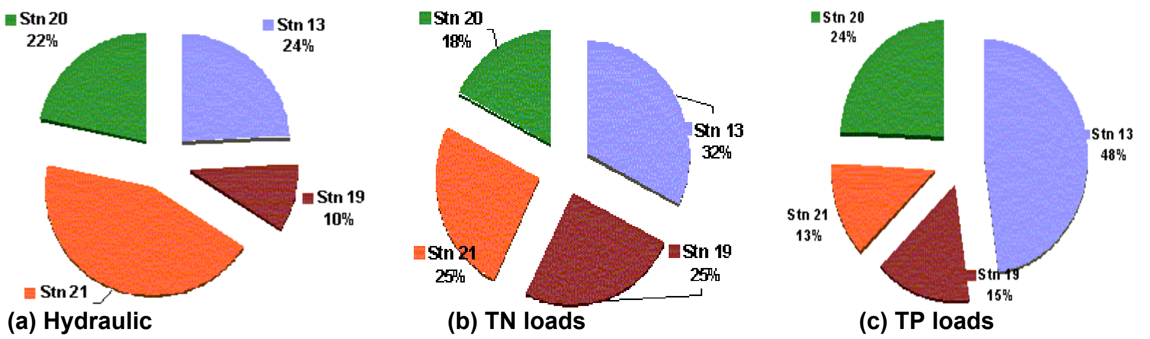

Figure 6: Comparative hydraulic and nutrient loads to Lake Chivero

4.2 Lake Nutrient Levels

Nutrient levels in Lake Chivero were highest in November 2000 mostly due to flush effects, as the rain season had just started. Fig 7 shows the nutrient levels from July 2000 to February 2001. The nutrient concentrations remained higher than permissible levels of 0.3 mg/l for nitrates and 0.01 mg/l for phosphates.

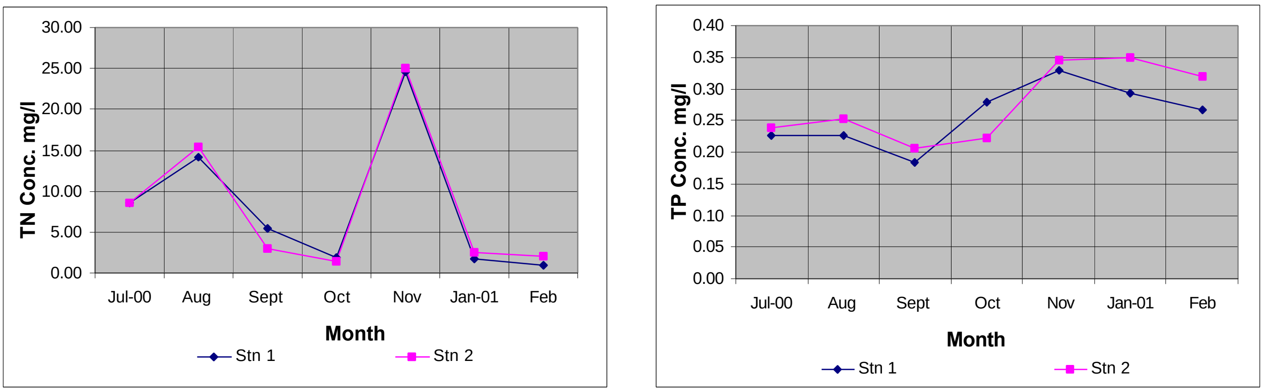

Figure 7 Nutrient Levels at two stations in Lake Chivero; July 2000 to February 2001

4.3 Pollutant Mass Balance Analysis

A pollutant mass balance was developed based on flow and nutrient concentrations as shown inn Fig 8. This diagram excludes seepage flows from the Firle/Ingwe/Pension Farm system.

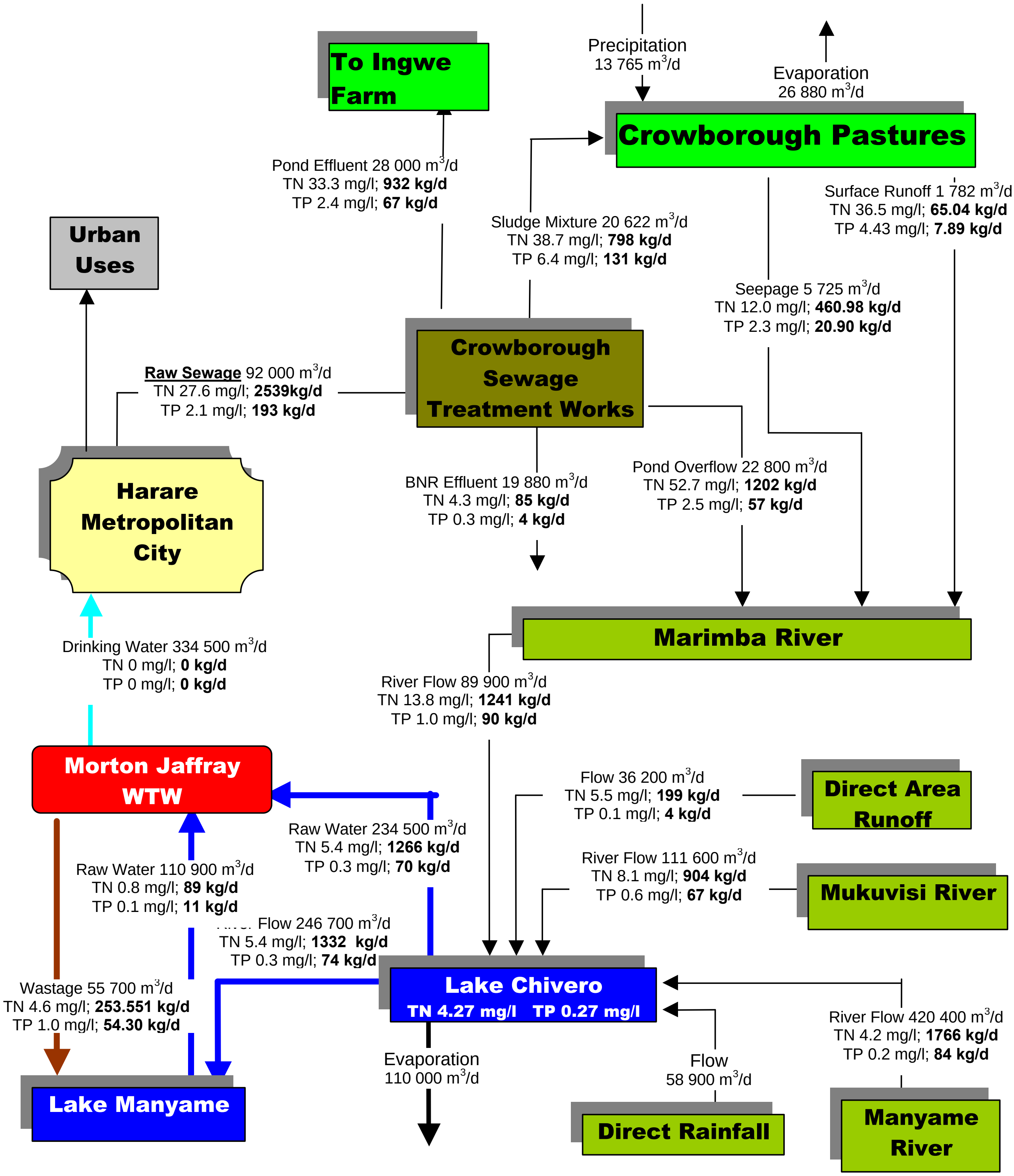

Figure 8: Water and nutrient flows in the Chivero Catchment

5. CONCLUSIONS AND RECOMMENDATIONS

There is need for a better planning system to avoid nutrient accumulation in the catchment. The following were concluded from this study:

1. Plans for a new water treatment have to be started now. After 2003 the existing plant capacity will have been exceeded.

2. The existing sewage treatment plants can no longer cope with the loads thereby stressing downstream water quality. New approaches to sewage management are required to ensure sustainability. Sewage flows to Lake Chivero need to be minimised. Sewage should be treated to higher standards (without any pasture irrigation) and discharged directly into the rivers for recycling. The other alternative is to recycle the nutrients in controlled urban agriculture, thereby reducing fertiliser runoff. Industrial pollution can be controlled by stricter regulations and regular monitoring.
3. Marimba and Mukuvisi Rivers are already heavily polluted before sewage discharge and further studies are required upstream to identify and control sources.
4. The recycling of polluted waters to Lake Chivero needs proper planning. A new source of water supply to Harare is required so that the water can help flush out nutrients from the Lake.

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Negotiating the rights of access to sufficient water through the courts

Lindie NIKLAAS* and Robyn Stein

Bowman Gilfillan Inc., PO Box 785812, Sandton, 2146

* l.niklaas@bowman.co.za

INTRODUCTION

This paper will examine the legal implications of the Grootboom judgement in view of the developing debate on socio-economic rights under the constitution on the constitutional right of access to sufficient water.

It will look at the manner in which effect is being given to this right at municipal level through the provision of free water and the constitutional implications of an adequate basic minimum level set by the State and local authorities, which does not in fact result in the provision of a survival minimum amount of water to vulnerable households.

The paper will also explore the implications of relevant legislation, which enables local authorities to cut off water supplies as well as the implications of the Grootboom decision for communities facing water cut-offs.

DEBATE ON SOCIO-ECONOMIC RIGHTS

Socio-economic rights tend to be positive in character and impose positive duties on the State. There was much debate as to whether it would be appropriate to include socio-economic rights in the final Constitution[1]. It has been affirmed that socio-economic rights are at least to some extent justiciable in that they can be 'negatively protected from improper invasion.'[2] Violation of these rights occurs when the state, through legislation or administrative conduct, deprives people of the access they enjoy to socio-economic rights. The duty to promote and fulfil socio-economic rights requires the State to take positive measures to assist those who currently lack access to the rights to gain access to them.[3]

The right to access to water as embodied in the Constitution is a socio-economic right. The issue however is how these rights are effectively exercised and what remedies are available to enforce them?

The Constitution provides that the State must take reasonable legislative and other measures, within its available resources, to achieve the progressive realisation of the right to sufficient food and water[4]. It further provides an independent guarantee against conduct that interferes with peoples' access to housing, health care, food, water and social security[5].

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[1] Glazewski J Environmental Law in South Africa, 2000
[2] Certification of the Constitution, 1996 at para 78
[3] Chaskalson Constitutional Law of South Africa pg 41-33
[4] Section 27(2)
[5] ss 26 and 27

The National Department of Water Affairs and Forestry's overarching responsibility is to create an enabling environment through which all people in South Africa can access water and sanitation services, and to support people in gaining access to these services.[6] To this end, the Department has enacted two pieces of legislation in an attempt to achieve its objectives to give effect to the right to sufficient water. These are the National Water Act[7] and the Water Services Act[8].

The Water Services Act provides that water service authorities are under a duty to provide all consumers with water services. The purpose of the National Water Act is to provide for water resource management, which achieves sustainable use of water for the benefit of all users. Further, the Department of Water Affairs and Forestry has undertaken to provide every household in the country with 6 kilolitres of free water per month.

LEGAL POSITION REGARDING WATER CUT-OFFS

Various legislation in terms of which authorities are empowered to cut off water supplies, judgements made in this regard, as well as their Constitutional implications will now be examined.

The main issue here is whether or not a local authority, which supplies water to consumers, can legally cut-off the consumers water supply as a result of the non-payment by the consumer for the service.

The Standard Water By-Laws provide that:" without paying compensation and without prejudice to its rights to obtain payment for water supplied to the consumer, the council may cut off the water supply to any consumer where such consumer has failed to pay any sum due to the council in terms of these by-laws.[9]

This legislative provision empowers local authorities to disconnect a consumer's water supply. This position was recognised in a number of decisions, which will be discussed briefly.

In *Coronation Freehold Estates, Town and Mines Ltd v Municipality of Balfour* [10], the court referred to a provision in the relevant by-laws proceeded on the assumption that disconnection for non-payment of charges in terms of this provision would be considered lawful.

Prima facie, disconnection for non-payment of charges would be lawful in terms of the powers granted to local authorities by the water by-laws.

Such disconnection would be rendered unlawful in two circumstances:

- if there exists some other provision which imposes on the local authority a duty to refrain from exercising its power to disconnect a consumers water supply for non-payment of charges; or
- if the legislative power to disconnect for non-payment of charges is in itself unconstitutional.

The next issue is whether there is a legislative provision, which places local authorities under a duty to refrain from exercising their powers to disconnect a consumer's water supply for non-payment of charges. To answer this question, we need to look at the provisions of the Public Health Act, before turning our attention to the impact of the Constitution.

[6] Human Rights Commission Report - Water
[7] Act 36 of 1998
[8] Act 108 of 1997
[9] Section 14(1)
[10] 1866 3 SA 724 (T)

In certain circumstances an authority's disconnection of a consumer's water supply might contribute to the creation of a "nuisance" on the premises. In *Mabela v Magistrate of Johannesburg*[11], it was held that the absence of a proper water supply for the tenant of certain premises constitutes a nuisance for the purpose of the Public Health Act[12]. The possibility that a nuisance might be produced as a result of the disconnection of a consumer's water supply cannot be said to impose on a local authority, a general duty to refrain from exercising its owner to disconnect for non-payment of charges.

While the authority has a duty to abate a nuisance, there is an anterior duty placed on the occupier of premises not to produce a nuisance in the first place. The authority's duty of abatement is therefore ancillary to the obligation of a landowner to refrain from creating a nuisance. The authority's duty of abatement is therefore only triggered when and if a "nuisance" has been created, and the existence of such a duty in particular situations cannot require it in advance to refrain from exercising a power to disconnect for non-payment of charges.

The Health Act 63 of 1977 provides as follows:
"Every local authority shall take all lawful, necessary and reasonably practicable measures –

> (a) to maintain its district at all times in a hygienic and clean condition;
> (b) to prevent the occurrence within its district of-
> (i) any nuisance;
> (ii) any unhygienic condition;
> (iii) any offensive condition; or
> (iv) any other condition which will or could be harmful or dangerous to the health of any person within its district or the district of any other local authority,
>
> or, where a nuisance or condition referred to in subparagraph (i) to (iv) inclusive has so occurred, to abate, or cause to be abated, such nuisance, or remedy, or cause to be remedied, such condition, as the case may be…[13]

An authority's duty in terms of the Health Act to maintain hygienic conditions and to abate a nuisance therefore does not require it to refrain from exercising its power to disconnect a consumer's water supply for non-payment of charges.

The Health Act defines "nuisance" as to include *inter alia* "any occupied building for which no proper and sufficient supply of pure water is available within a reasonable distance.[14]"

The Health Act is broad in that it places an authority under a duty to "prevent the occurrence" of any unhygienic or offensive condition. The authority is therefore not simply obliged to abate an unhygienic condition as and when it arises, but is also under a duty to take necessary steps in order to ensure that an unhygienic condition is not produced in the first place.

Attention should be drawn to the fact that the Health Act clearly contemplates that payment will be made for services. It provides as follows:" in so far as any local authority is not already authorised thereto by any law, that local authority may –

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[11] 953 3 SA 17 (T)
[12] Act 36 of 1919
[13] Section 20(1)
[14] Section 1

(a) determine:
  (i) the moneys payable for a service resulting from any function in terms of this Act;
  (ii) the circumstances in which the conditions under which such moneys shall be payable; and
  (iii) the basis on which such moneys shall be calculated;

(b) on application by any person, in writing exempt such person from the payment of such moneys.[15]"

The Health Act further provides that "the provisions of this Act shall not derogate from any rights or functions assigned to any body established by or under any law for the purposes of the supply of water.[16]"The power to disconnect a consumer's water supply for non-payment of charges in terms of the water by-laws, is a "right" for the purposes of the Health Act. Any contention that the Health Act restrains an authority from exercising its powers to disconnect a consumer's water supply for non-payment of charges would clearly involve a derogation of that "right". Such derogation is barred by virtue of the Health Act.

The Constitution provides as follows:

"(1) Everyone has the right to have access to …
  (a) …
  (b) sufficient food and water …
  (c) …

(2) The State must take reasonable legislative and other measures, within its available resources, to achieve the progressive realisation of each of these rights.[17]"

The right of access to sufficient water raises the possibility that the legislative provisions, which empower the authority to disconnect a consumer's water supply for non-payment of charges, may now be unconstitutional.

The Constitution states that:" The State must respect, protect, promote and fulfil the rights in the Bill of Rights[18]"This provision raises the possibility that an authority might be under a constitutional duty to refrain from exercising its powers to disconnect a consumer's water supply for non-payment of charges in circumstances where such a course of action will produce a violation of the Constitution.

IMPLICATIONS OF THE GROOTBOOM JUDGEMENT

This decision broadened the concept of socio-economic rights by holding that the concept of adequate housing included not just a dwelling but access to land, services including electricity and refuse collection and market facilitating devices including non-discriminatory finance and municipal planning.[19]

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[15] Section 20(1A) (which was inserted by Act 188 of 1993)
[16] Section 55(3)
[17] Section 27
[18] Section 7(2)
[19] Flynn S The right to essential services- A Constitutional analysis of water and electricity policy in the new South Africa

The Grootboom judgement made it clear that social and economic programmes designed to meet constitutional obligations cannot pass muster if they leave the poorest people and those in intolerable or crisis situations from their purview. It is not enough, to point to a long-term programme that provides relief for people eventually. Programmes must be tailored to provide some sort of immediate relief for the people who need it most.[20]

Mrs Grootboom and the other respondents applied for an order directing the appellants to provide:

- adequate basic temporary shelter or housing to the respondents and their children pending their obtaining permanent accommodation
- or basic nutrition, shelter, healthcare and social services to the respondents who were children.

This claim was based on two constitutional provisions. The first provision being that everyone has a right of access to adequate housing[21]. The second provision relied on was that children have the right to shelter[22].

With respect to the claim in terms of the right to access to adequate housing, the High Court held that the state was faced with massive shortage in available housing and a constrained budget. In terms of the pressing demand and scarce resources, they had implemented a housing programme in an attempt to maximise available resources to redress the housing shortage. For this reason, it therefore could not be said that they had not taken reasonable legislative measures within their available resources to achieve the progressive realisation of the right to have access to adequate housing.

With respect to the claim of the children for shelter, the court reasoned that the parents bore the primary obligation to provide shelter for their children, but that the Constitution imposed an obligation on the State to provide that shelter if the parents could not. The court concluded that an order, which enforces a child's right to shelter, should take account of the need of the child to be accompanied by his or her parent.

As a result the Constitutional court ordered the following:

- the applicant children are entitled to be provided with shelter by the appropriate organ or department of state;
- the applicant parents are entitled to be accommodated with their children in the aforegoing shelter; and
- the appropriate organ or department of state is obliged to provide the applicant children, and their accompanying parents, with such shelter until such time as the parents are able to shelter their own children.

In reaching this decision, the court held that the right to access to adequate housing couldn't be seen in isolation. There is a relationship between it and other socio-economic rights. The implication of this is that the State is under a duty to provide access to sufficient water in as much as it is under an obligation in terms of Grootboom to provide adequate shelter for children. The court was however of the opinion that the Constitution did not entitle the respondents to claim shelter or housing immediately upon demand. The Constitution does however, oblige the State to

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[20] opcit
[21] section 26
[22] section 28(1)(c)

devise and implement a coherent, co-ordinated programme designed to meet its constitutional obligations. The programme that had been adopted and was in force in the Cape at this time were inadequate in that they failed to provide any form of relief to those desperately in need of access to housing. The court therefore ruled that the State was under an obligation to meet the obligation imposed on it by the Constitution. This includes the obligation to devise, fund, implement and supervise measures to provide relief to those in desperate need.

This judgement raises the issue of whether the provision of free water is adequate in terms of the States obligation to provide access to sufficient water under the Constitution, taking into account the needs of those desperately in need of adequate water services.
This case also has implications on whether or not an authority can exercise its right to cut off a consumer's water supply for non-payment of charges if that consumer does not have the resources to pay for the service.

In this respect, it is necessary to look at the case of *Residents of Bon Vista Mansions v Southern Metropolitan Local Council*[23]. The residents of Bon Vista Mansions instituted this action because their water supply had been discontinued. They sort interim relief on an urgent basis, for the reconnection of their water supply. The court held that the council was under an obligation in terms of the Constitution to achieve the realisation of the right of access to water. The court referred to the International Covenant on Economic, Social and Cultural Rights and the analysis of this Covenant by Chaskalson P that in order to respect a right, the State must refrain from action, which would serve to deprive individuals of their rights. The court further made reference to the general comment made by the committee in relation to food, where is was said that the obligation to respect existing access to adequate food requires the State parties not to take any measures that result in preventing such access.

The court held that the applicants had existing access to water before the Council disconnected the supply. The act of disconnecting the supply was prima facie in breach of the Council's constitutional duty to respect the right of access to water, in that it deprived the applicants of existing rights.

The court stated further that the Water Services Act, seeks to create a statutory framework within which such a breach may be justified. The Act does this by providing that a water service provider must set conditions in terms of which water services are to be provided and these include the circumstances under which water services may be limited or discontinued and the procedures for limiting or discontinuing such services.[24] The Act further provides that the procedure for the limitation or discontinuance of water services must be fair and equitable and provide for reasonable notice of intention to limit or discontinue water services and for an opportunity to make representations, unless other consumers would be prejudiced; there is an emergency situation; or the consumer has interfered with a limited or discontinued service; and not result in a person being denied access to basic water services for non payment, where that person proves, to the satisfaction of the relevant water services authority, that he or she is unable to pay for basic services.

The court therefore held that if a local authority disconnects an existing water supply to consumers, this is prima facie a breach of its constitutional duty to respect the right of existing access to water, and requires constitutional justification. The conditions that can be set in terms of the Water Services Act for discontinuing a service must be fair and equitable and must provide for reasonable notice of termination and for an opportunity to make representations. They must not result in a person being denied access to basic water services for non-payment where that person

[23] unreported WLD judgement
[24] Section 4(1)(c)(iv) and (v)

proves,to the satisfaction of the water services authority that he or she is unable to pay for basic services.

The court therefore held that the applicants had a prima facie right to a continuing supply of water. The right was being infringed in that they had been deprived of access to water, and the deprivation was continuing.

Another case in point is the case of *Manqele v Durban Transitional Metropolitan Council.*[25]The applicant here was an unemployed woman who occupied premises with seven children. Her water supply was disconnected as a result of her non-payment of her water account.

The applicant sought a declaratory order that the discontinuation of basic water services to the premises occupied by her and her dependants was unlawful and invalid in that the by-laws in terms of which the discontinuation was effected was *ultra vires* the Water Services Act, the respondent utilised procedures for discontinuation which did not comply with the Act and it resulted in the applicant and her dependants being denied access to basic water services for non-payment where she was unable to pay for the services.

The applicant in this case relied on her right to basic water supply as referred to in the Water Services Act and not in terms of the Constitution. The Water Services Act provides that one of its main objectives is to provide for the right of access to basic water supply and the right to basic sanitation necessary to secure sufficient water and an environment not harmful to human health or well being.[26]The Act further provides conditions for the provision of water services that include the determination and structure of tariffs, the circumstances under which water services may be limited or discontinued and procedures for limiting or discontinuing water services. The act provides that the procedure for the limitation or discontinuing of water services must not result in a person being denied access to basic water services for non-payment, where that person proves, to the satisfaction of the relevant water services authority, that he or she is unable to pay for basic services.

The Act defines "basic water supply" as the prescribed minimum standard of water supply services necessary for the reliable supply of a sufficient quality and quantity of water to households and "prescribe" means prescribe by regulation. However, no regulations in this respect have been promulgated.

As a result of this, the respondent argued that was therefore no content to the right to a basic water supply. In an endeavour to supply basic water services, the respondent had adopted a policy of providing the first six kilolitres of water per month free to domestic consumers. All consumers are required to pay for water consumed in excess of this basic service. The applicant's water consumption per month far exceeded the basic six kilolitres free service provided by the respondent.

The court held that it was clear that Water Services Act was directed at achieving the right embodied in the Constitution. However, in the absence of regulations defining the extent of the right of access to a basic water supply, the court had no guidance from the legislature or executive to enable it to interpret the content of the right embodied in the Act. The court therefore held that the right upon which the applicant relied was incomplete and therefore unenforceable.

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[25] unreported Durban and Coast Local Division judgement
[26] section 2(a)

Both the *Bon Visa Residents* case and the *Manqele* case were based on the right to access to water. The main difference between them however, is the fact that one was based on the Constitution and the other on the Water Services Act.

The *Manqele* decision however highlights the issue of whether or not the provision of 6 kilolitres of free water per month is an adequate basic minimum level. This level is based on a minimum of 25 litres of water per person in a household of eight people. The problem however, is the fact that not all households consist of eight people and in fact the poorer households tend to consist of more than eight people. This results in inequality in the sense that the people in the smaller households have access to more free water per day than those in larger households.

It can therefore be argued that this provision of free water is insufficient particularly for the people who need it most. The argument is that the amount of free water that a household is entitled to should depend on the size of that household and a blanket allocation is insufficient. The problem with this contention though is that it could be difficult to ascertain the number of people per household and to ensure that their individual water bills reflect their unique position. One could argue that a mechanism does exist to rectify this in that people who cannot afford and prove that they cannot afford to pay for their water are exempt from water cut-offs both in terms of the Constitution and in terms of the Water Services Act

The conclusion is that there are no legislative provisions, which impose on an authority a duty to refrain from exercising its power to disconnect a consumer’s water supply for non-payment of charges as long as it does not result in the depravation of water to somebody who proves that they cannot afford to pay for the water.

PROCEDURAL REQUIREMENTS

It is pertinent to consider whether the Constitution imposes any procedural requirements that the authority will need to comply with before disconnecting a consumer's water supply for non-payment of charges.

The water by-laws provide that the council 'may' serve a notice on a consumer whose account is in arrears in order to warn the consumer of the possibility that his or her water supply will be disconnected for non-payment of charges[27]. It is clear that this section authorises the authority to serve such a notice without requiring it to do so.

It is necessary to consider whether certain procedural requirements might be ‘implied’ by virtue of the Constitution. We will consider the following possibilities in turn:

- does the Constitution require an authority to afford a consumer a hearing before it exercises its power to disconnect a consumer's water supply for non-payment of charges?
- does the Constitution require the authority to obtain a court order before it exercises its power to disconnect a consumer's water supply for non-payment of charges?

THE NEED FOR A HEARING

The Constitution contains an administrative justice provision, which provides as follows:

“Every person has the right to –

[27] Section 10(a)

(a) lawful administrative action where any of their rights or interests is affected or threatened;
(b) procedurally fair administrative action where any of their rights or legitimate expectations is affected or threatened;
(c) be furnished with reasons in writing for administrative action, which affects any of their rights or interests unless the reasons for that action have been made public;
(d) administrative action which is justifiable in relation to the reasons given for it where any of their rights is affected or threatened[28]."

The Constitution guarantees a right to 'procedural fairness' only in circumstances where two conditions are satisfied. These are:

- the conduct in question must amount to "*administrative action*"; and
- the conduct must affect or threaten a person's *'rights or legitimate expectations'*.

The authority's exercise of its power to disconnect a consumer's water supply for non-payment of charges should properly be construed as 'administrative action', which is susceptible to review on administrative-law grounds.

This conclusion is supported by *Basson tla Repcomm Repeater Services v Postmaster General*[29], where the court held that since the issue of a licence was an 'administrative disposition' rather than a contract, it was subject to judicial review. The discretionary powers conferred on the respondent cannot be exercised arbitrarily and must conform with well defined guidelines relating to *inter alia* the rules of natural justice, the rules against ulterior purpose, the rules against the unreasonable exercise of a discretion and the rules against *male fides*[30]"

It is likely that an authority's exercise of a power to disconnect a consumer's water supply for non-payment of charges would be held to affect the 'rights' of that consumer for the purposes of the Constitution.

Since a consumer's right to obtain water is made dependant on payment of the relevant charges under the water by-laws, it might be thought that disconnection of the water supply for non-payment of charges could not possibly amount to interference with any 'right' on the part of the consumer.

It seems, however, that this contention is no longer good law after the decision of the Appellate Division in *Administrator Natal v Sibiya*[31]. In this case public servants had been dismissed on notice, and without being afforded a hearing. It was argued on appeal that there could be no room for the application of *audi alteram partem* since a public sector employee whose contract of service is terminable on notice has no legal 'right' to remain in his employment after the expiry of the notice period. The Appellate Division rejected this argument in decisive terms. The court was of the view that the argument misconceived the requirements of the *audi* rule. The rule does not require that the decision of the public body should, when viewed from the angle of the law of contract, involve actual legal infraction of the individual's existing rights. It involves simply that the decision should adversely affect such a right.[32]"

[28] Section 23(2)(b)
[29] 1994 3 SA 224 (SECLD)
[30] supra at 233C
[31] 1992 4 SA 532 (A
[32] at 538G-H

Sibiya suggests strongly that an authority's disconnection of a consumer's water supply for non-payment of charges would amount to interference with a 'right' possessed by the consumer. The argument is of application if the relevant 'right' on the part of the consumer is understood to be a constitutional right of access to water rather than a right to continued water supply under the water by-laws.

It is concluded that an authority’s exercise of its powers to disconnect a consumer's water supply for non-payment of charges amounts to 'administrative action’, which affects the 'rights' of consumers. It follows that those consumers have a right to 'procedural fairness' in terms of the Constitution.

'Procedural fairness' does not necessarily require an oral hearing in circumstances where this course of conduct would be impractical. There is no reason why the constitutional requirement of 'procedural fairness' may not similarly be satisfied by inviting consumers to make written representations before an authority exercises its power to disconnect their water supply for non-payment of charges.

‘Procedural fairness' for the purposes of the Constitution would in appropriate cases be satisfied by the adoption of a similar procedure. The disconnection of a consumer's water supply for non-payment of charges seems to be well suited to such a procedure, since it would clearly be impractical for an authority to afford every defaulting consumer an oral hearing. 'Procedural fairness' in the present context requires that an authority should give notice of its intention to disconnect a consumer's water supply, and should invite the consumer to make written representations before it exercises its power of disconnection.

The need to serve such a notice is in fact rendered mandatory by virtue of the constitutional right to procedurally fair administrative action. The notice should not merely inform consumers of their outstanding charges, but should warn them of the possible disconnection of their water supply and should invite them to make written representations as to why this course of action should not be followed in their case.

It is important that the authority’s procedures should comply with the following two conditions:-

- There should be a sufficient interval between the taking of the decision and its implementation to allow for representations to be made by those consumers whose water supply is liable to be terminated for non-payment of charges.
- the authority must retain an open mind so as to allow itself to be persuaded to reverse its earlier decision to disconnect a consumer's water supply for non-payment of charges if that consumer is able to establish good cause. Good cause here would include an inability to pay for the services.

THE NEED FOR A COURT ORDER

The water by-laws do not require an authority to obtain a court order prior to exercising its power to disconnect a consumer's water supply for non-payment of charges. The question, which arises, is whether the requirement of a court order may nevertheless be 'implied' by virtue of the Constitution or any other legal provision.

If it were to be contended that an authority's disconnection of a consumer's water supply for non-payment of charges requires a court order, then some reliance might also be placed on the Constitution. It provides that 'everyone has the right to have any dispute that can be resolved by the application of law decided in a fair public hearing before a court or, where appropriate, another independent and impartial tribunal or court.[33]'

An authority's power to disconnect a consumer's water supply for non-payment of charges must be exercised in accordance with the requirements of 'procedural fairness'. There is no need to obtain a court order, but the authority should serve written notice on defaulting consumers in order to warn them of the possible disconnection and to invite them to make written representations.

CONCLUSION

This paper is premised on the prevailing philosophy that water is a commodity for which consumers are required to pay. That is a philosophy which might, in certain circumstances, be at odds with the guarantees of the Constitution and particularly the obligation of the State, in terms of the Bill of Rights". However, there are situations where people are simply too poor to pay for water. In such circumstances, there may well be a constitutional obligation to provide a minimum quantity of water without charge in order to sustain life itself. This pre-supposes the availability of adequate resources to fulfil this obligation. The constitutional source of the obligation may be the Constitution which provides that "everyone has the right to life.[34]"

This right may apply in circumstances where there is an existing supply of water to a consumer but the consumer is too poor to afford payment. The constitutional obligations in question may well be construed to impose an obligation to provide a minimum life-sustaining amount of water without charge, obviously having regard to available resources.

The right to access to water is in itself a basic human right. The State is therefore under a constitutional duty to ensure that all the people in South Africa have access to sufficient water to meet their basic needs. The State has taken a step toward achieving this by making available free water to every household. This however, does not cater for those individuals who are not connected to water systems, e.g. people living in the rural areas who still have to fetch water from rivers. The impacts of this have come to the fore in the recent cholera pandemic, which affected lots of people. One could argue that the State has thus failed, to provide these people with access to sufficient water.

It is clear from the case analysis done here that the right to water can be enforced through the courts particularly as it is a right protected by the Constitution.

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[33] Section 34
[34] Section 11

Determining parameter reliability levels in a digital information system for monitoring and managing hydrological droughts

W R NYABEZE

Water Systems Research Group, University of the Witwatersrand, P Bag 3 Johannesburg, WITS 2050, RSA

WashingN@civil1.civil.wits.ac.za

ABSTRACT

Hydrological droughts expose discrepancies between location of water resources and demand centers, resources available and requirements. As a drought becomes more severe the need for precise decisions on a course of action is amplified. Information derived from analysis of observed parameters values can be used in managing the risks associated with such actions. However, a major concern is the gap between actual and measured parameter values. This tends to widen with increasing temporal and spatial scales especially in heterogeneous catchments. This paper describes the measurement system common to rainfall, runoff, evaporation, demographic parameters and other parameters relevant for drought monitoring and management. It explores techniques to estimate and display reliability indices for spatial and temporal analysis. Recommendations are made on how to track improvement or deterioration in reliability of parameter values.

Keywords: *drought management; Information Measurement System; reliability; error estimation; pre-processing*

INTRODUCTION

The historical 1991/92drought exposed the lack of timely information and analysis tools on water resources, uses and users in Zimbabwe (Makurira, 2001). A computer model is being developed which integrates information on these elements in a geographical information system (GIS) to facilitate rapid and accurate interpretation of drought scenarios. This model comprises the following sub-models:

(a) Information pre-processor
(b) Runoff estimator
(c) Yield estimator
(d) Charts and statistics and
(e) Maps and statistics

The model is compiled using Visual Basic on Windows 98 platform and it is linked to GIS software, Microsoft Access and Excel. The focus of this paper is on the pre-processor, which is used to scrutinize available digital information, patch and re-configure it for application in the model. This paper highlights some of the issues in this process.

INFORMATION FOR MANAGING DROUGHT

In the model information is being assembled in a database, which is divided into the following parameter groups:

- Climate
- Water resources
- Demography
- Social and cultural
- Economic
- Environment
- Geophysical

Each parameter group name explains the intended content of that group.

CLIMATE

In the current version of the model (Version R1A0801) the Climate group has monthly time series of rainfall and evaporation. This data was provided by the Meteorological Department. In the pre-processor time series are patched to fill in for missed observations and to get better representation at the selected catchment scale. This data is then configured for direct reading in the runoff estimator. Locality, record and gap length are captured into a database file readable in the GIS software. Data capture errors are minimized to 5% of the observed value (Banderson, 2001).

GEOPHYSICAL

Parameters in the climate group interact with those in the geophysical group in the hydrological cycle. In the model these interactions take place in the Runoff Estimator, which is a modified Visual Basic Version of Wits University's Rafler model. Links to Microsoft Access and Excel and GIS software and parameter relationships are being improved continuously. Runoff is also output in text-delimited format. The geophysical group is further divided into sub-groups, which profile the catchment, land cover, land use and soils. Different institutions are generating their own digital data sets for different purposes. The accuracy achieved is not known and conditions of access vary from no access to excessive costs (Kwesha, 2001). A working scale of 1:250 000 has been adopted in the model being developed. Some activities such as scanning, geo-referencing and vectorising take place outside the pre-processor.

WATER RESOURCES

The water resources group includes parameters on rivers, reservoirs and abstractions. Observed monthly time series of runoff, summaries of annual abstractions and spatial covers of rivers and lakes were obtained from the Department of Water Resources. For the time-series the length of record is variable and gaps are common (Madamombe, 2001). Covers not yet available include boreholes, wells, springs, ground water potential and water quality. The Zimbabwe National Water Authority (ZINWA) maintains the national database for this information. According to Siwadi (2001) the United Nations Ground Water for Windows (UN-GWW) in current use is not directly convertible to Micro Soft Access. However, in the pre-processor available data can be configured for direct reading into the charts, maps and statistics sub-models. Locality, record and gap length are also captured for readout in the GIS software.

ENVIRONMENT

The environment group comprises parameters on flora and fauna. The intention is to break down the environment group into sub-groups, which can relate to water ecological water requirements. Collaboration is expected from the Department of Natural Resources has been low and it is anticipated that problems may be encountered on getting accurate parameter values. Food, livestock production and vegetation covers are available on 1: 250 000 scale. There are guidelines on production of accurate digital sets (Kwesha (2001). This means that the reliability of most of this information is unknown.

DEMOGRAPHY

In the Demography Group the total population to be served with water during droughts and the settlement patterns are important parameters. Population totals per Ward for 1992 were obtained from the Central Statistics Office and digitized. The model already has 1: 250000 digital spatial covers of Wards. Accurate estimates of unit water consumption are required.

SOCIAL, CULTURAL AND ECONOMIC

The society is the main user of water through social, cultural and economic activities. The society and its culture stand out clearly as one group and the economy as another group. Distinct activities are to be picked out in each group and parameterized. Reliable parameter values are required to reflect the true water requirements for economic, social and cultural activities in settlements. Estimates of minimum, expected and economic levels of service are required. The minimum level could be based on health or activity sustenance similar to the approach used by the National Early Warning Unit in estimating food deficits (Dube *et al*, 2001). Parameters are also required to model the effect of social, cultural, economic measures in managing through scarce water conditions (Stephenson, 2001).

IMPROVING RELIABILITY OF PARAMETER VALUES

This model uses parameter values, which are determined by measurement, surveys. Application of a relatively simple pre-processor has shown that reliability of most parameters required for drought monitoring and management in Zimbabwe is unknown. This shortfall can be address by first analyzing each parameter measurement system to identify possible sources of errors. Once these are known probable error values can be assigned. Such values can be used to derive reliability indices. A typical measurement system is shown in figure 1.

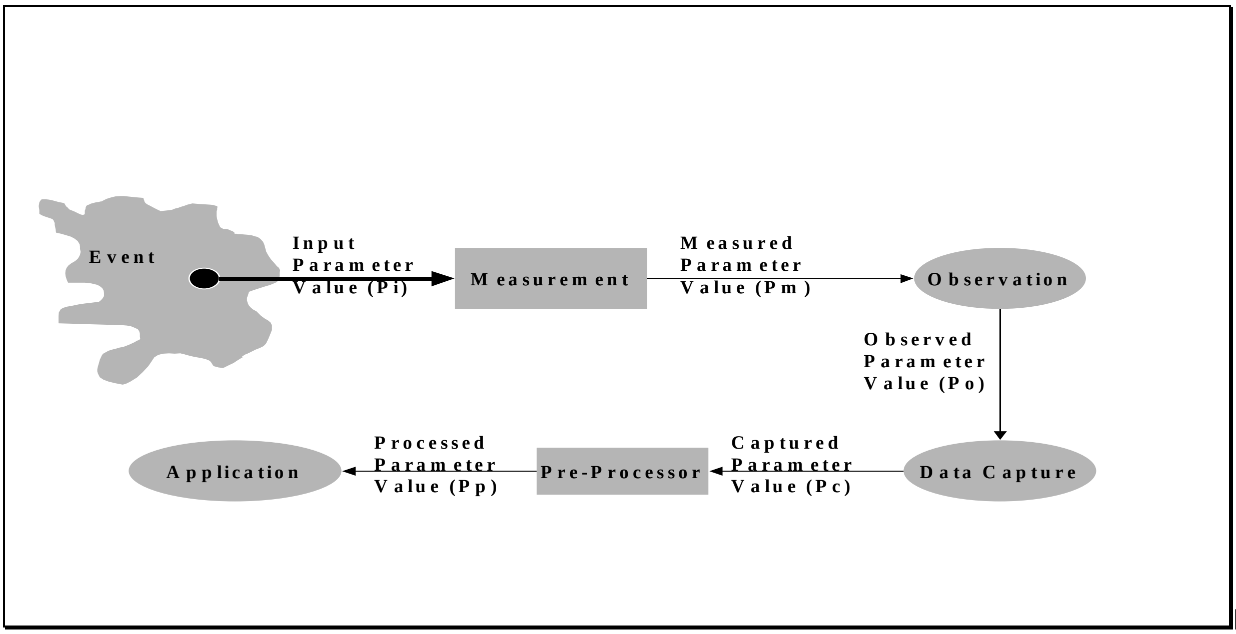

Figure 1: Typical Information Measurement Systems

By virtue of the methods used the measured value (P_m) is always distorted in some way. According to accepted terminology the real value of a parameter is called the correct value and the sensed value is the measured value (Boros 1989). The measure of distortion is called " error". The input parameter value (P_i) is not equal to P_m thus even at an early stage in the measurement system the exact value of P_i is unknown. Steady state conditions are essential for a measurement to be taken at the measurement point. At steady state the input parameter has discrete minimum and maximum values. These are represented by P_{imin} and P_{imax} and P_{imax}–P_{imin} defines the input range. It is further assumed that the measurement system responds to the input parameter value in discrete steps. Its resolution would be the largest change in input value ΔP_i that can occur without a change in the measured value P_{mi}. This defines the minimum measurement step and can be related to the spatial and temporal density of measurement points.

The resolution of the measurement system is then defined as:

$$100x\Delta P_i / (P_{imax} - P_{imin})$$

The rate of change of P_{mi} with respect to P_i

$$dP_{mi}/dP_i$$

defines the sensitivity of the measurement system. In the ideal case rate of change of P_{mi} with respect to P_i should be a constant K but in reality there is also a non-linear component $N_{i.}$ The range of non-linearity can be expressed as a percentage of the parameter value to be measured:

$$100xN_{imax} / (P_{imax} - P_{imin})$$

$N_{i.}$ also varies with P_i thus;

$$\text{Sensitivity} = K + dN_i / dP_i$$

As dP_i becomes small sensitivity increases but the opposite occurs for high values of dP_i. Out of 30 "automated" weirs inspected on this study all of them require manual adjustment to match the requirement for reduced or increased sensitivity (Nyabeze, 2001). The occurrence of runoff in most catchments of Zimbabwe is such that the frequency of adjustment required is in the order of magnitude of hours or day or two, which can overwhelm most observers. Inspection showed that sensitivity is best matched in the middle range flows and there is generally a poor match for low flows. The expression on sensitivity can be rewritten as:

$$dP_{mi}/dP_i = K + dN_i / dP_i \text{ ………………….(i)}$$

Integrating (i)

$$P_{mi} = KP_i + N_i + c \text{ ………………………..(ii)}$$

In (ii) the intercept c typically represents build up of P_{imin} before start of response from measurement system. It can also be taken as the threshold of previous events essential to cause the response in the current event. Of the 30 runoff weirs inspected on this research over 60% of them were too wide for adequate head to build up during low flows. A review of measurement systems on rainfall, evaporation, runoff and population has shown that they actually end with equation (ii) and in practice the values of N_i and c are assumed to be constant throughout the life of the measurement system. Other inputs such as development can shift the steady state condition in time and space in a manner that makes it difficult to relate P_{mi} to P_i. These shortfalls can be addressed by review and recalibration of the systems supported by stochastic approaches.

Environmental effects can introduce linear P_{ienvl} as well as non-linear P_{ienvn} inputs to the measurement system (Boros, 1989). These inputs affect the sensitivity of the measuring system. Considering the linear component of the environmental input P_{ienvl} then the linear sensitivity of the measurement system is changed from KP_i to

$$KP_{mi} + K_{ienvl}P_{ienvl}$$

Environmental inputs can change the intercept from c to;

$$c + K_{ienvln}P_{ienvn}$$

This can be referred to as a zero bias. Environmental effects can cause positive or negative effects and this is implicit in the equations above.
Thus equation (ii) becomes;

$$P_{mi} = KP_i + K_{ienvl}P_{ienvl} + N_i + c + K_{ienvln}P_{ienvn} \ldots\ldots\text{(iii)}$$

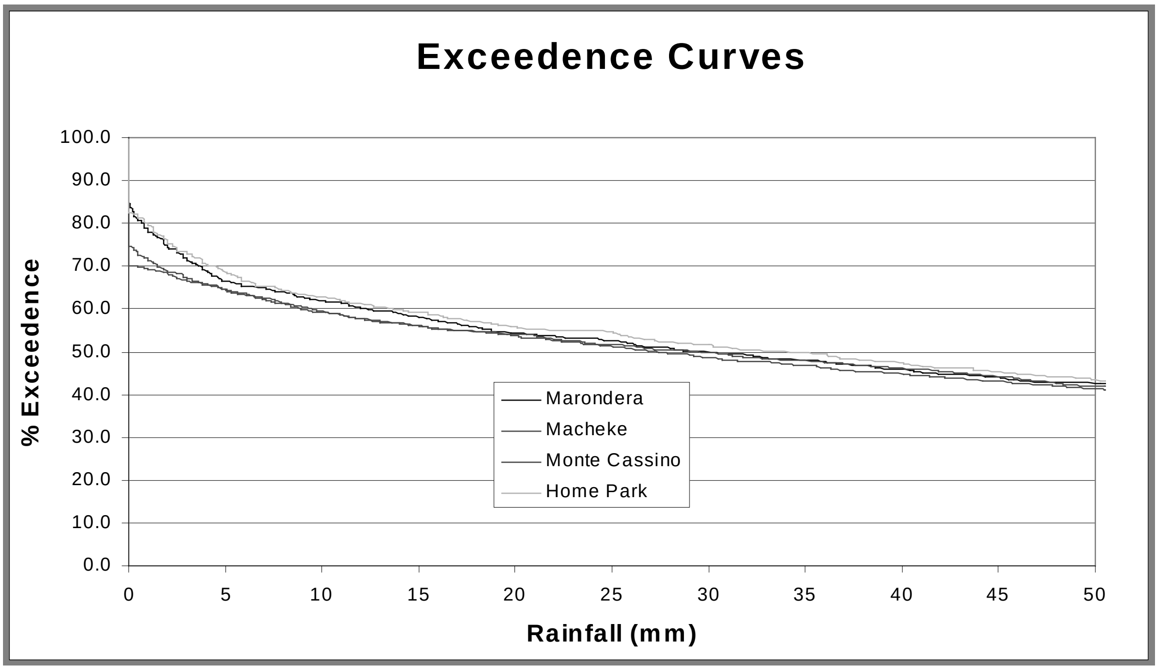

Figure 2: Exceedence Curve for Selected Rainfall Stations.

Equation (iii) shows that the measured value P_{mi} comprises, a factored input value, an environmental input, a non-linear component, zero intercept and an environmental component that affects the intercept. The actual parameter value can be worked out by re-arranging equation (ii) as follows:

$P_i = (P_{mi} - K_{ienvl}P_{ienvl} - N_i - c - K_{ienvln}P_{ienvn})/K$……..(iv)

The environmental inputs P_{ienvl} and P_{ienvn} fluctuate randomly with time if K_{ienvl} and K_{ienvln} are not zero. This causes of lack of repeatability. Where the processed parameter values of P_p and P_{mi} are nearly equal or closely related exceedence curves can be used to patch missing record by relating P_{mi} across systems. Figure 3 shows that for low rainfall situations Macheke and Monte Casino can cross-relate and also Marondera and Home Park. Obviously such cross-relation is more accurate for monthly rather than daily time-scales.

The environmental component affecting the intercept can be identified through inspection and re-calibration. For example recalibration can account for the effects of siltation, which is a common phenomenon on runoff stations. The frequency of re-calibration depends on silt trap efficiency of the observation station and effectiveness of de-silting exercises.

Figure 3: Runoff Station

In most measurement systems the environmental input is often ignored resulting in incorrect information. It is not uncommon for measurement systems to go without review and recalibration.

Characteristics of the measuring system also change with time. These changes can be minimized by timely review and replacement of components or whole measurement systems.

In addition the measurement system may follow a different path when moving from high values to low values and from low values to high values as illustrated in figure 4.

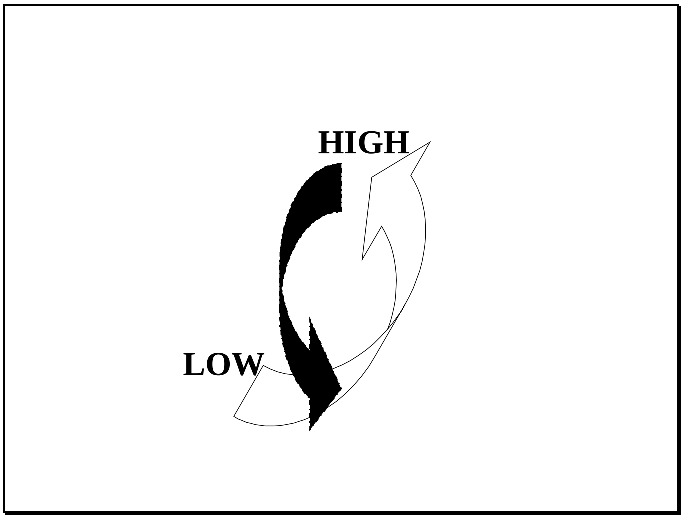

Figure 4: Hysteresis in Measurement Systems

This path defines the hysteresis of the system $H_{mi,}$ which can be calculated from:

$H_{mi} = P_{mihigh} - P_{milow}$……………………………………………………..(v)

The maximum hysteresis can be expressed as a percentage of the maximum and minimum measured values;

$100 \times H_{mimax}/(P_{mimax} - P_{mimin})$

Unfortunately the management of most measurement systems and deployment of resources in Zimbabwe typically reinforces this hysteresis. A lot of activity takes place around the natural events causing the low and high signals diminishing rapidly after the events. These activities are often out of phase with the events, consequently accurate records of signals from the event are missed.

Hysteresis can be minimized by:

- Provision of adequate resources including motivated personnel on time
- Improved understanding of the environmental component and its occurrence
- Improved management

The common practice is to lump measurement errors into two categories namely random errors and systematic. These errors are then detected through measurement of the same event using over 30 different techniques or measurement systems followed by application of statistical techniques. In this way it has been possible to get within 5% of P_i on runoff measurements errors (Herschy, 1995). However, in the context of a developing country this intensity of measurements and measurement systems is not feasible mostly because of lack of finance for intended coverage. However, from the discussion presented in this paper a solution may be found in a better understanding the components of the input signal and the parameter measurement system.

Discussion of faulty equipment has been left out of this paper as the solution is repair or replacement. Of the 30 runoff stations inspected on this research equipment on over half of them was faulty.

Post measurement stages include observation (P_o) data capture (P_c) and pre-processing (P_p) before a value can be applied. Most institutions have the human resources but lack computer hardware and software to maintain integrity of information in all these stages. The handling of large volumes of measurements is difficult and can introduce more errors to measured values. The use of different formats can reduce resolution of information. Errors from post measurement stages can be determined by inspection, and benchmarking against standards adopted from those already in application across the world. Some of these can be obtained from the Standards Association of Zimbabwe (SAZ).

The model being developed on this research has a sub-model to fill in missing runoff records by mimicking conditions in a catchment. Although such estimated values (P_e) cannot substitute for actual measurements (P_m) they are a realistic option where data is missing. In water scarce conditions values of (P_e) can be used to check on (P_m) and vice versa.

WHAT ARE THE CHALLENGES?

Even in the most extreme drought exploitation of water resources should be within their natural range of recovery and bridge he drought with no loss of life. The experience in managing droughts in Zimbabwe shows that this ideal is not being met, which raises the following questions on the information available for management decisions.

(i) How reliable is the information available?

As discussed in this paper hydrological droughts are at the lower end of the hysteresis loop and the reliability of most information gathered under such circumstances is generally suspect. In this paper it has been shown that errors are encountered starting from parameter measurement to the preprocessing stage. At parameter measurement errors typically arise from failure to account for the:

- Lower threshold of response
- Non-linear component
- Environmental effects
- Deviations from steady state conditions

Post measurement errors typically arise from:

- Observation
- Data capture and
- Pre-processing

Error estimates can be assigned for these different stages. Reliability indexing can be introduced by summing the errors. This indexing can be informed by inspection, review, and evaluation of the information measurement systems. Reliability indices can be expressed as percentages for example ±10% and it is important to provide these with the parameter values. Knowledge of the probable difference between the actual and measured parameter value informs the decision maker of the chances of erring as a result of application of the information. Before such decisions are made a sensitivity analysis can be made using parameter values within the reliability range. These indices also pave the way for commercialization of information sets. They can provide motivation to achieve higher accuracy. Without reliability indexing confidence in the information is compromised.

(ii) How widely is the information applied?

It is evident from past drought experiences that most information is not seriously applied in managing droughts. The real value of information is in its application to support decisions and barriers to information flow and processing result in most databases being of sentimental value only.

IMPROVING RELIABILITY OF PARAMETER VALUES

Without information on reliability decision makers can find it difficult to rely on the information provided. Reliability of parameter values can be enhanced by improvements in measurement systems complemented by the use of statistical methods to identify errors and their causes. Some techniques, which can improve reliability of parameter values are described in the following section.

(a) Projections

Where the density of measurement system is inadequate in temporal and spatial scales available information can be projected. A typical example involves population. The size of a population (P_{si}) continues to change. It can decrease or increase due to the following factors:

- Natality (birth rate)= dN_a/dt
- Immigration (movement of new individuals into an area from another one) = dI/dt
- Emigration (movement of individuals from an area to another one)= dE/dt
- Mortality (death rate) = dM/dt

Thus the rate of change in population size is defined by:

$$dP_{si}/dt= (dN_a/dt+dI/dt)-(dE/dt+ dM/dt)\ldots\ldots\ldots\ldots(vi)$$

On integrating this becomes:

$$P_{si} = N_a+I-E-M+c\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(vii)$$

In Zimbabwe population counts are carried out once every ten years. Reliable growth rates are required to project population totals for droughts periods, which may fall in between census years. Such growth rates can be used in projecting the consequences of current actions on future drought scenarios.

It has been observed that when social, economic and environmental conditions are favorable (dN/dt+dI/dt) tends to exceed (dE/dt+dM/dt) and the population increases however from the last part of the 20th century the impact of the Aids/HIV epidemic has introduced non-linearity. The economic performance of settlements also affects dE/dt and dI/dt and to a lesser extends dN/dt and dM/dt). All these factors affect the input parameter value (Psi). The measured or observed population size still conforms to equation (iii). The processor being developed can be used to verify the measured or estimated data by calculating population densities and reading them on to a GIS cover of Wards. This database is classified and the classes are then used to check low and high-density areas. In the model each catchment has a separate population database file and projections are done in Microsoft Excel. There is provision to assign growth rates at the Ward level but these figures are not yet available.

(b) Increasing Density of Measurement

In the simplest and ideal case, to monitor an event which occurs at a point P_i (x_1, y_1, z_1), F times in a period T, T/F observations are required if all events are to be captured. If the characteristics of the event or its occurrence are affected by preceding events then more observations are required to capture these other preceding events. Furthermore if the characteristics of the event at another point

P_i (x_2, y_2, z_2) are significantly different from those at the first point P_i (x_1, y_1, z_1), then a different set of observations is required for the second point. On the temporal scale if we consider that we have a drought occurring every F years surely we cannot go beyond F years without review of the related parameter measurement systems. Increase in density of observation is also essential to account for development and to check reliability of parameter values. In the pre-processor the temporal density of each measurement system is constructed for viewing on GIS. This database has provision for displaying years elapsed since last review of the measurement system.

(c) Evaluation of Measurement Systems and Information

This model is being designed to handle a large volume of information. Its architecture is being developed to take advantage of the improvements in computer processing speed and random access memory (RAM) to configure information for analysis and interpretation. When fully developed it can rapidly perform frequency analysis and output a range of statistics including maximum, minimum, mean and median values. Charts of time series can be drawn up to relate causes and effects. Such output can be used to evaluating measured information.

Measured values can be fitted into known functions and these functions can be compensated for fluctuations caused by environmental and random inputs. In this model these computations occur in sub-models developed in Visual Basic and linked to Microsoft Excel.

As part of the evaluation process measurement systems should be inspected. In most cases inspection involves checking components of a measurement system. This research is supported by inspection of different measurement systems.

(d) Taking Advantage of Advances in Digital Information Systems

Where there are physical and human constraints to adequate monitoring advantage can be taken of advances in tele-metering, remote sensing and satellite technology. This model is linked to GIS software, which enables integration of satellite images.

(e) Investment in Human Resources

Most measurement systems require motivated personnel to sustain them religiously even in the most difficult conditions.

CONCLUSIONS

The reliability of information for drought management can be improved but the starting point should be a clear understanding of the measurement systems and the possible sources of errors. A model is being developed with a pre-process that can be used to track improvements or deterioration in quality of parameter values but this requires a parameter to index errors. This index can sum up the errors from sensing at seven distinct stages in a measurement system. Reliability indices are essential for sensitivity analysis. Results from such analysis can inform decision makers on the likely impact of “informed” errors.

Improvements in reliability of information can be achieved in a number of ways, which include:

- Application of projections.
- Increasing density of measurements systems.
- Evaluation of measurement systems and information supported by reliability indexing.
- Tele-metering, remote sensing and satellite imagery.
- Investment in human resources and

- Reducing variations in formats of the measured information.

All these methods involve costs, which should be weighed against financial loss and negative impact of decisions made on the basis of inaccurate information.

ACKNOWLEDGEMENTS
The co-operation for ZINWA staff in all the catchments visited in support of this research is acknowledged. This paper has been produced under a research project funded by the Water Research Fund for Southern Africa (WARFSA).

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Effect of sanitation facilities, domestic solid waste disposal and hygiene practices on water quality in Malawi's urban poor areas: a case study of South Lunzu Township in the city of Blantyre

L. G. PALAMULENI

Chancellor College, Dept. of Geography and Earth Sciences, PO Box 280, Zomba, Malawi

lpalamuleni@unima.mw

ABSTRACT

Household water supply problems remain one of the major challenges facing developing countries. In Malawi, there is lack of documentation on the levels and causes of water pollution particularly in peri-urban areas so that meaningful interventions can be adopted. Therefore, a study was carried out in South Lunzu Township a peri-urban area in the City of Blantyre.

The study revealed that the major form of sewerage disposal is the on-site sanitation system where about 58.8% of the respondents use traditional pit latrine while in terms of solid waste disposal, the Blantyre City Assembly which is responsible for solid waste collection, has only two collection vans to cater for more than half a million residents (BCA, 1999) hence indiscriminate disposal rampant in the area.

Water samples collected from the major sources of domestic water supply showed that there are variations in the levels of water pollution between ground water and surface water sources and between the wet and the dry season. For instance, physically, the ground water turbidity levels were in the range of 2mg/l to 12mg/l during the dry season but increased to a maximum of 114mg/l during the wet season while for surface water the turbidity increased from 4mg/l to 408mg/l over the seasons compared to the WHO standard set at 5mg/l and the Water Department standard set at 25mg/l. Chemical pollution for surface water sources show seasonal variations with an increase in the concentration during the wet season, for instance, iron levels ranged from 2.3 mg/l to 4.03mg/l. This is above the WHO and Water Department drinking water standards, which are 1mg/l and 3mg/l respectively. However, bacteriologically, both the ground water and the surface water sources are grossly polluted. Ground water spring coliform count ranged from 190/100ml to 9,500/100ml; and the well 3,500/100ml to 11,000/100ml having the maximum during the wet season. Surface water results also indicated the coliform count ranging from 2,900/100ml to 4,600/100ml way higher than the WHO, MBS standard for drinking water which is 0 and the Water Department standard for untreated water of which range from 10-50 coliforms/100ml.

The results indicate that water resources have been polluted by lack of sanitation facilities, indiscriminate disposal of waste and the institutional set-up governing the provision of services in the area.

INTRODUCTION

Access to safe clean water and adequate sanitation is a fundamental right and a condition for basic health. However, in the developing world, one person in three lacks safe drinking water and sanitation. In these nations, an estimated 80% of all diseases and over one-third of the deaths are caused by the consumption of contaminated water. For example, only 2% of Bangkok's population is connected to sewers, Khartoum's municipal sewerage covers 5% of the urban area while Jarkata and Kinshansa have no sewerage at all (UNEP, 1998). In Malawi, only 6% of the population has access to proper sanitation and 39% of the population has no access to latrine (GOM, 2000). However, within the urban areas there are disparities in the provision of services. In the city of Blantyre, the sewer pipe serves only 8.3% of the city's population while 77.7% living in the squatter and traditional housing areas use pit latrines as the major form of sewerage disposal. Thus, in these urban areas, on-site sanitation offers the only cost effective alternative to sewerage system. Nevertheless, where population density is high, pollution may result because these are often located in close proximity with utilised water resources. The situation may be exacerbated by the hydrogeology of the area, which permit persistence, and mobility of the pollutants. In Migosi, Kenya for instance, pit latrines located 20.5 metres from usable wells registered high levels of faecal coliforms and total coliforms which resulted in outbreaks of cholera, typhoid and dysentery (UNEP, 1998).

Lack of solid waste disposal systems is also threatening water resources in urban areas. In Jaipur, India, wells had high levels of chloride; sulphate, bicarbonate and ammonia due to a solid tip located 450 metres away. The collection of solid waste in Malawi's urban areas is a problem where only 30%, 28%, 8% and 8% of the waste was collected from Lilongwe, Blantyre, Mzuzu and Zomba respectively leading to indiscriminate refuse dumping (GOM,2000). In the peri-urban areas, domestic waste collection is not done at all. Thus, disposing of wastes can give rise to serious pollution of ground water and surface water resources especially where there is uncontrolled tipping. As such, lack of adequate sanitation facilities continues to threaten water resources in urban areas.

From the lessons learnt on water and sanitation programmes implemented in the past, it is imperative that hygiene education be integrated in such projects. Water supply systems and sanitation facilities are directly linked to behavioural practices in the communities. Some pollutants get into the human system because of such practices as not covering food, eating unwashed food, not washing hands and drinking untreated water. For instance, a common transmission route of the bacillary dysentery, amoebic dysentery and diarrhoeal diseases is from man's faeces by flies to food or water and thence man (Rajagopalan, 1974). Thus, hygiene practices play a role in harmonising provision of clean potable water supply and sanitation systems.

This paper discusses the results of the effect of sanitation facilities, solid waste disposal and hygiene practices on water quality in South Lunzu Township.

The main objective of the study was to determine the causes and extent of water quality pollution in South Lunzu Township in the City of Blantyre. Specifically, the study was aimed at determining the types of water pollution, their levels and identifying the factors which have led to the degradation of water resources in the different sources.

METHODOLOGY

The main sources of data for this study were through structured questionnaires, personal interviews with key informants and collection of water samples from the study area.

Questionnaire Survey and Sampling

The questionnaire used in the study was administered to 160 households who were randomly selected from the study area. Information gathered from the interviews included the characteristics of the respondents in terms of sex, educational level, employment, the sanitation facilities they have, solid waste disposal methods, sources of water supply and some basic hygiene practices prevalent in their homes.

Key Informant Interviews

Interviews were held with key personnel in the urban area as well as the study area. These are the officials from the Blantyre City Assembly (BCA), Blantyre Water Board (BWB), Department of Water and the Public Health Surveillance at South Lunzu Health Centre. The aim of the interviews was to establish the extent of water resources degradation in the area, the provision of potable water and sanitation services, and the problems being encountered by the service providers.

Water Sampling

Four sets of water samples from nine sampling points were collected- two during the dry season and two during the wet season. Samples were collected from ground water sources which included a borehole, Nkhumbe spring, Namilango spring and Msopa well. From surface water i.e. along Lunzu River from four sampling points positioned one at the entry point into South Lunzu Township, another one at the exit of the study area and two within the study area. Tap water provided by the BWB was also collected from Machinjiri Market to act as a control that is if people were provided with tap water, what is the quality.

The sampling sites were basically chosen purposively after a pilot survey of the area. These are the extensively used sources of water for different activities including drinking, cooking, bathing and washing.

RESULTS

Characteristics of Households

The household interviews conducted in South Lunzu Township indicates that on-site sanitation is the best alternative to other forms of sewage disposal. There were four categories of latrines which were identified in the area. The majority, 58.8% of the respondents have the traditional pit latrine, where a hole is dug in the ground 2-3 metres deep and is not lined at all. From the survey, 0.6% of the respondents have water closets connected by a septic tank. Small proportions of the respondents about 5% have ventilated improved pit latrines, which are believed to be environmentally friendly. These latrines have brick wall superstructures, a cover on the hole and pipes inserted outside for ventilation.

The presence of household sanitary facilities and their condition is another important aspect of public health. Facilities such as dustbin refuse pit and bath shelter ensures the cleanliness of the home because waste is disposed of in designated places. The study showed that 66% of the respondents have and use refuse pit while 16.3% use dustbins. However, after using a dustbin, once it is full, the wastes are dumped either along the street or along the river at night because BCA does not collect refuse from this area. This practice is a threat to water resources in the area.

The provision of clean potable water is another challenge facing the people of South Lunzu Township. It was noted that among the married couples, 88.7% find water rates to be very high and 72.5% of the respondents indicated that they do not even think of having household piped water system because it is just too expensive. Table 1.0 below indicates that 83.1% use tap water, 8.8% use ground water and 8.1% use surface water for drinking.

Table 1.0 Percentage Distribution of Respondents by Sources of Domestic Water

Source of Water	Drinking		Cooking		Bathing		Washing	
	No of res.	%	No.of res	%	No. of res	%	No. of res	%
Tap water	133	83.1	131	81.9	122	76.2	119	74.4
Ground water	14	8.8	14	8.7	14	8.8	14	8.7
Surface water	13	8.1	15	9.4	24	15.0	27	16.9
Total	160	100.0	160	100.0	160	100.0	160	100.0

However, due to the prohibitive nature of piped water, in addition to low pressure which is usually coupled with intermittent supply, people in the area have other sources of water such as springs, wells, borehole and from Lunzu River. Water from these sources is used for domestic activities, which include cooking, drinking, washing and bathing. Table 1.1 below shows that about 88% mentioned that they use spring water which is available throughout the year, others opt for well water while others have no choice but to use water from Lunzu River.

Table 1.1 Percentage Distribution of Respondents by Supplementary Source of Domestic Water

Supplementary Source	No. of Respondents	Percent
Spring	142	88.7
Open Well	4	2.5
River	7	4.4
Private Tap	7	4.4
Total	160	100.0

However, 90.1% of the respondents indicated that they do not treat their water in any way regardless of the water source. The treatment done at household level by 9.9% of the respondents include boiling, filtering with a clean cloth and chlorinating with chlorine tablets. These respondents mentioned that they usually treat their drinking water during the rainy season because of high incidence of water-borne diseases.

Provision of potable water supply by itself will not necessarily prevent infection. It is apparent that improvements in sanitation and personal habits should accompany the efforts to improve water supply. Education in simple applied hygiene is essential. Having the knowledge and actually doing it are two different things. Respondents were asked on some of the basic hygiene practices which they do in their households. It was interesting to note that 4.4% of the respondents do not wash their hands before and after eating food; 8.1% do not wash their hands even after visiting a latrine; 49.4% do not wash their hands after handling child's excreta; 50.6% do not wash their hands even when they are dirty. Such practices can be routes to some diseases even when water supply and sanitation systems are clean.

Water Quality in South Lunzu Township

As may be expected, water quality in South Lunzu Township is not uniform. Of interest are the variations between the surface and ground water sources on one hand and between the dry and wet season on the other. Table 1.2 indicates the physical variations of water in South Lunzu Township. During the dry season, surface water turbidity is within the Water Department standard for drinking water of 25 mg/l but above the WHO standard of 5 mg/l. However, at the on-set of the rainy season, the levels have increased to as high as 442 mg/l. Turbidity for ground water differed depending on the location of the water source. Water from the borehole and Nkhumbe spring had clear natural colour during both seasons indicating non-turbid water. Namilango spring and Msopa shallow well had high turbidity level exceeding WHO and Water Department standards.

Table 1.2 Physical Pollution of Water in South Lunzu Township

Name of site	Turbidity	S.solids	E.Conductivity	pH
1.Upstream	4±1, 408±6	5±1, 6304±4	400±4, 600±5	7.83, 7.21
2.Middle	8±1, 283±2	7±1, 2789±3	380±2, 629±1	7.59, 7.21
3. L. Middle	8±0, 301±1	7±1, 2735±4	390±5, 442±2	7.85, 7.7
4.Downstream	7±1, 442±2	6±0, 1770±8	400±2, 640±1	7.58, 7.8
5.Borehole	2±0, 1.3±0.8	2±0, 1.0±0	330±3, 342±2	6.55, 7.1
6.Nkhumbe sp.	3±0, 5.6±0.2	1±0, 4.3±0.5	180±1, 306±1	6.52, 7.37
7.Namilangosp.	11±1, 114±0.5	13±2, 165±0.8	210±2, 331±2	7.06, 7.87
8. Msopa Well	3±0, 65±0.8	2±1, 65.5±0.5	290±3, 383±2	6.38, 7.5
9. Tap Water				
WHO Stds	5	15	Not available	6.5-8.5
WaterDept.stds	25	50	Not available	6.0-9.5

NB: Site 1-4 rep. Surface water, site 5-8 rep. Ground water
First result for dry season, second result for wet season

The suspended load of the dry season water samples which range between 5 mg/l to 7 mg/l, are within the acceptable limit for drinking water set by WHO and Water Department. At the on-set of the rainy season, the levels of suspended solids are extremely high. The ground water sources have low suspended solid levels compared to the standards ranging between 1 mg/l for Nkhumbe spring to 13 mg/l for Namilango spring. During the wet season, Nkhumbe spring registered only 4.3 mg/l of suspended solids. Msopa well and Namilango spring had increased suspended solid levels as high as 65.5 mg/l and 165 mg/l respectively.

The pH results for the water samples in South Lunzu Township are within the recommended limits and they range between 6.38 and 7.89 hence they satisfy the WHO and Water Department standards.

Table 1.3 shows the chemical concentration of water in South Lunzu Township. The results of both surface water and ground water samples collected during the dry season indicate low levels of sodium, chloride, fluoride and iron. At the on-set of the rainy season, some minerals increase in their concentrations. For example, iron levels increased from 0.25 mg/l to 4.03 mg/l in the upstream section of Lunzu River.

Table 1.3 Chemical Pollution of Water in South Lunzu Township

Name of site	Sodium	Iron	Chloride	Fluoride
1.Upstream	28.6±0.5,31.8±1.3	0.3±0.1,4.0±0.4	31.9±0.9,31.4±1.2	0.98±0.01,1.02±0.08
2.Middle	27.6±0.5,32.6±0.1	0.6±0.1,3.5±0.1	31±0,30.1±0.1	0.87±0.01,1.01±0.08
3. L. Middle	27.6±0.5,26.2±0.1	0.3±0.1,2.4±0.1	36.1±0.1,23.6±0.1	0.97±0.02,1.02±0.02
4.Downstream	27.6±0.5,30.8±0.2	0.3±0.1,2.3±0.1	36±0,31.3±0.9	0.88±0.05,1.01±0.01
5.Borehole	16.3±0.5,16.6±2.3	0.3±0.1,0.6±0.1	21.9±0,20.4±0.1	0.87±0.01,0.37±0.02
6.Nkhumbe sp.	16.6±0.5,24.3±0.9	0.1±0.1,0.7±0	21±0.9,13.6±0.7	0.9±0.1, 0.46±0
7.Namilangosp.	21.0±0.1,20.8±0.2	0.2±0.1,0.6±0.1	21.1±0.1,27.8±0.1	0.89±0.01,0.48±0.01
8. Msopa Well	15.9±0.1,15.3±0.5	0.8±0.1,0.4±0.1	35±0.1,28.7±0.6	0.87±0.01,0.44±0.09
9. Tap Water				
WHO Stds				
WaterDept.stds				

NB: Site 1-4 rep. Surface water, site 5-8 rep. Ground water
First result for dry season, second result for wet season

Ground water sources constitute the main source of water supply in the area. Table 1.4 below shows the bacteriological ground water results obtained during both seasons and they are grossly contaminated including tap water supplied by BWB.

Table 1.4 Levels of Faecal Coliforms(FC) and Faecal Streptococci (FS) in Groundwater

Sample Site	Organism Type and Levels Registered for Groundwater/100ml							
	Dry Season				Wet Season			
	Sample 1		Sample 2		Sample 1		Sample 2	
	FC	FS	FC	FS	FC	FS	FC	FS
Borehole	2	0	0	0	-	-	30	0
Nkhumbe Sp.	270	10	190	50	730	204	2,000	0
Namilango Sp.	1,070	200	530	220	9,500	7,000	3,000	0
Msopa Well	5,200	640	3,500	530	4,250	2,650	11,000	250
Tap Water	0	1	89	0	0	3	2	0
WHO Stds	0							
Water Dept Stds	0-50							

The borehole is showing little contamination within the Water Department standard although it is important for regular sanitary checks to be done on the equipment. The faecal coliforms are excremely high during the rainy season with Msopa well registering as high as 11,000/100ml.

Table 1.5 Levels of Faecal Coliforms(FC) and Faecal Streptococci (FS) in Surface water

Sample Site	Organism Type and Levels Registered for Surface water/100ml							
	Dry Season				Wet Season			
	Sample 1		Sample 2		Sample 1		Sample 2	
	FC	FS	FC	FS	FC	FS	FC	FS
Upstream	6,100	520	2,900	1,040	16,000	15,500	18,500	6,600
Middle	4,200	380	2,500	1,400	8,500	6,000	12,200	1,400
Lower Middle	1,100	230	4,600	6,500	17,000	10,500	400	500
Downstream	5,200	640	750	1,420	15,500	12,000	3,000	1,600
WHO Stds	0							
Water Dept Stds	0-50							

Table 1.5 shows high levels of both faecal coliform and faecal streptococci with the maximum levels during the wet season in the surface water sources.

DISCUSSION

As seen from the physical results, the activities taking place along the river are increasing physical pollution in the water. For instance, the high levels of turbidity and suspended solids in the water could be due to the brick making and sand collection done by the residents. During the wet season, bare land left after construction, cultivation of marginal river line sections has accelerated run-off and erosion thereby increasing the levels of turbidity and suspended solids in surface water sources. The ground water sources have variations in the levels of physical pollution depending on the location of the source. For instance, Nkhumbe spring had low levels of pollution because of the sand bedding while Msopa well and Namilango spring had high levels due to the gully above these sources, which deposits fine suspended and colloidal particles of clay and silt. The levels at the on-set of the rainy season were extremely high because of increased erosion and run-off.

Water in South Lunzu Township is less threatened from chemical pollution. Pliny, R (1985) concluded that water takes the properties of the rocks through which it passes. Hence, the ground water sources reflect the geological characteristics in the area. Thus, rocks in South Lunzu Township are the perthitic syenite and pyroxene granulite gneiss, which yield low levels of such minerals as sodium, iron, and fluoride among others. However, with increased erosion during the rainy season, leachate from the indiscriminate disposal of waste taking place in the area could contribute to high levels of some of the minerals especially in surface water.

Bacteriologically both surface water and ground water in South Lunzu Township is grossly polluted. As indicated, South Lunzu is a densely populated area characterised by on-site sanitation and indiscriminate disposal of refuse. This has resulted in the high levels of faecal coliforms and faecal streptococci. These high levels in the ground water sources can be attributed to the geology of the area which has fissures and fractured pegmatite veins in the basement aquifers. These facilitate recharge processes and seepage from nearby latrines and septic tanks hence ground water sources vulnerable to contamination.

The surface water, that is, Lunzu River is contaminated by run-off and soil erosion from the peri-urban area and industrial area. Renwick, H.L. (1985) observed that some trace substances both organic and inorganic have a tendency to travel attached to particles rather than being dissolved. In addition, Lunzu River is passing through Maone Wastewater Treatment works, Kachere and Nkolokoti Townships. As such, the high pollution levels in the river could be due to the raw sewage being discharged in the river (since the wastewater treatment works is not working) and also run-off and sub-surface flow from the two townships. In addition, the people involved in brick making along the river have no sanitary facilities hence they use the river as a disposal system. It should also be mentioned that the washing of clothes includes nappies which contribute to the bacteriological pollution in the river.

CONCLUSION

Poor design of on-site sanitation systems and lack of disposal and collection of solid waste are accelerating water pollution in South Lunzu Township.
Therefore, it can be concluded that the growth of urbanisation in Blantyre city is putting a pressure on resources and services. Many sub-city aquifers are polluted with human waste because few of the urban population is connected to main sewer line. The poor design and lack of maintenance of pit latrines, septic tanks and even the sewer lines continue to put a threat to water resources in the urban area.

Bareland left after construction, building in marginal lands has accelerated surface run-off and erosion thereby increasing faecal matter carried by these rivers.
However, community participation could help improve the water situation in the area thereby ensuring a health environment.

ACKNOWLEDGEMENTS

I am greatly indebted to United Nations Development Programme through the Department of Environmental Affairs for the financial assistance rendered to make this research a success.

Special thanks to my supervisors: Dr. M. B. Dolozi, Dr. W. R. L. Masamba and Mr. Jeke for their guidance and constructive critisms.

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Preliminary comparison between natural water resources and poverty in Mozambique Part I: Rainfall

Luiz Magno Ranchordo PEREIRA[1] and Farizana OMAR[2]

Agronomist[1 & 2] and Geophysicist[1], Universidade Eduardo Mondlane, Faculdade de Agronomia e Engenharia Florestal, C.P. 257, Maputo

luiz_magno@hotmail.com

ABSTRACT

Climatic fluctuations and water scarcity, severely disturbs human development in Mozambique. Natural disasters that have water as a principal role player are those that impacts strongly on the quality of life of our population. Availability of water through a sound management of water is a problem.

When rains are in abundance, people suffer from flood and the crops are lost due to water logging. When rainfall is scarce drought becomes a problem. Population never knows the type of weather that will occur. They are faced with a high level of uncertainty in decision-making when planning their agricultural production.

This study aims to evaluate the similarity and dissimilarity between rainfall distribution and poverty. In the meantime, it will be analyzed the spatial and temporal fields of rainfall and their variability and the spatial distribution of poverty in the country in 1996. With this information a preliminary comparison between natural water resources and poverty can be achieved.

It was found that in dry areas there is a strong similarity in patterns between rainfall and poverty distribution. Although most of the central and northern part of the country has got enough rainfall to practice good agriculture, it is surprising to see that some of these areas also suffer of severe poverty. In fact, the actual level of development of the country, have not yet dumped satisfactorily the bad effects of climate on infrastructures, housing, agriculture, industry and population security, among many others.

We can clearly see that abundance of water from rainfall is not the solution of problem. So we propose that we have to move into an effective water management with a strong component on hydraulic infrastructures.

It is recommended to survey natural resources and evaluate and built infrastructures in favor of the more vulnerable communities clearly demarcated in the map of the poverty distribution in the country such as those high populated areas located across the Zambeze Valley downstream to the Indian Ocean.

The southern region of the country has a privilege of historical commercial relations with South Africa, a developed country. The central and northern regions due to their economical "weak" geopolitical position, has to find commercial relations not only within the region but also far away with other developed nations of the world. This apparently weak geopolitical position can be reversed to a position of advantage, with the application of an adequate strategy where our resources and potentials on soil and subsoil, climate, hydrology and access to the ocean are conveniently exploited.

I. INTRODUCTION

According to Pinstrup-Anderson (1998), the economic and human development in many regions of the world is severely affected by food insecurity, which is caused by climatic fluctuation, among others. Permanent inhibition of all individuals to physical and economic access to sufficient food in order to sustain an active and healthy life, results in food insecurity (MPF, 1998).

Mozambican government has defined a strategy to combat poverty defined as PARPA Ginja (2000). PARPA intends to do the following:

i) Correction of regional asymmetry of poverty incidence;
ii) Expansion of educational opportunities with priority to the women and for the rural areas;
iii) Sustained economic development with a preferential standard for agro-industry;
iv) Increase productivity in agriculture;
v) Development of economics infrastructures in the rural zones;
vi) Reduction of dependency rates of the family aggregate.

From the interventions actually conducted, a majority in emergency actions, through the Department for Combat and Prevention Against Natural Calamities (DPCCN) (today National Institute for the Management of Natural Calamities (INGC)), the National Institute for Rural Development (INDER) and also the World Food Programme (PMA) and a profusion of NGO's, the Mozambican population have not evolved notably in relation to the reduction of their vulnerability to the natural phenomena. They take no advantages from the natural resources available e.g. water and climate. They are, frequently, exposed to the climacteric effects that cause severe environmental damages, such as droughts, floods and even rain in excess. Due to the lack of internal defenses, these populations suffer human and material losses to the small climacteric phenomena and socio-economic instability, MS e MPF (1997).

We can clearly find that excess and lack of water are of major concern. To sustain population growth it is required to supply water in quantity and quality that is vital to life. According to Simons, 1998, the increasing lack of water urges us to develop an appropriate and equitable management of water, to assure that actual and future populations can live in a situation of sufficiency including certainly the poor and the oppressed. Those must benefit to the partition of water according to their rights.

Environmental impacts, such as the destruction of agriculture production and the weak network of terrestrial communications, the frequent occurrence of pests, plagues and diseases, makes difficult the transition from a plan of emergency to a plan of development which can overcome in the long run the poverty and sustain and adequate quality of life (Fabbri, 1995).

To attain an adequate quality of life we need to know perfectly the resources we have available and its potential for development. We are aware that technology, means and industrial infrastructures, commercial and social, especially those in the area for the production of food, education and health are there and can be easily acquired. But, planning and dimensioning infrastructures requires the knowledge of the natural resources potential and its behavior. To make decisions, on what type of transformation has to be made in order that populations benefit in an equitable and sustainable way, we need to know better about our resources and target.

The objective of this communication is to trigger the analyses of indirect factors that relates or influences poverty. In this first tentative we analyze how rainfall as a natural resource is correlated with poverty in Mozambique.

2. MATERIALS AND METHODS

To evaluate any existing correlation between poverty distribution in the country and rainfall distribution, various, rainfall related fields where produced and compared with spatial poverty distribution. Those fields were the normal rainfall distribution in specific months, and the field of rainfall deviation from the average in the region. A map of population concentrations was produced in order to further evaluate the impact of the previous field patterns on population poverty.

Point data was interpolated and mapped using SURFER 6.04 (1996). Kriging linear was utilized. Rigging is a geostatistics interpolation method and it produces contours and surface maps from data irregularly distributed. This method results in a map that shows the tendency that data suggests.

2.1 Rainfall fields and its variability

Rainfall data herein used where obtained from FAO (1984) and are the monthly normals of 164 locations in the region enclosed between -8° e -29° latitudes and 27° e 41° longitudes. With those data maps displaying total annual and monthly normals for the months of October, January and June (Fig.1 (a), (b), (c), (d)) were produced. The “deficient” distribution of rainfall is effectively demonstrated in a map were the deviation of the normal rainfall from the region average is plotted and contoured (Fig. 2(a).

2.2 The field of occurrence of absolute poverty

The local occurrence of absolute poverty was determined with the computation of the percentage of individuals below the Poverty Line. Poverty Line is defined as the minimum consumption and income necessary to attain the minimum well-being. Regarding to consumption it was included spending on food and no food items. Regarding to income it was included the monetary value. The poverty line was conceived to include different population habits and living costs. For such, the country was divided in 13 regions, but taking in common the value of 2200 calories per day that a meal has to have per person, according to the (WFP and UEM, 1998).

The field of occurrence of absolute poverty distribution was obtained by interpolation using non-uniform distributed data of the Poverty Incidence Index (PII). PII estimates the proportion of people whose consumption (or other indicator to estimate the Living Standard) falls below the Poverty Line. With a number of poor persons **q** in a population of size **n,** PII is given by **q/n**. PII was obtained after a national survey to the family aggregates on life conditions in 1996. The quantity of poor persons was evaluated with the measurement methodology proposed by Ravallion (1998). With the same methodology as used with rainfall a strictly domestic map was produced as shown in Figure 2©. Transboundary data was not available. So, the map reflects the state of our country. But, the economic influence on Mozambican people from neighboring countries can be evaluated as a direct effect on Mozambican people well being, especially on harsh Mozambican regions. The map cannot be extrapolated to the people living across Mozambican borders. So, contours out of Mozambican borders and into the ocean are not valid.

3. RESULTS AND DISCUSSION

3.1- Spatial and temporal distribution of rainfall

The spatial distribution of rainfall in Mozambique is highly irregular. Although irregular, some homogeneous regions can be identified such as semi-arid, moist and intermediate. Rainfall distribution is locally modulated by latitude, topography and coastal shape. The movement across the region of the equatorial low pressure and subtropical high pressure belts, driven by the sun's apparent movement to the south and to the north, causes a cyclic behavior in rainfall occurrence and its distribution in the region.

Rainfall is in general above 1000 mm north of parallel 20º S, exceptions are found in province of Tete at south of Zambeze River. Intertropical Convergence Zone brings rain up to parallel 20º S, culminating its activity and coverage in January. Elevated zones in the mountain range are those who get extreme rainfall. South of this parallel, rainfall is fairly inferior to 1000 mm. It falls mostly in the coastal zone and decreases rapidly to the interior of Gaza, attaining 400 mm in Chicualacuala.

The temporal distribution of rainfall across the year is modulated from the motion of two virtual waves, one coming from the south and other from the north. The south wave comes first in September and its peak occurs in the second week of February with rainfall moving from the coastal zone to the interior. It stops also first from the interior to the coastal zone. This phenomenon causes a very short cropping season in the south interior. The north wave attains 20º S and is normally very active, persistent and extensive to inland. This characteristic, guarantee with more certainty, rainfall occurrence in time and quantity in the northern regions of the country.

During normal years, September becomes very hot with a lot of humidity in the air. Onset of rains occurs late in this month. October, announces the beginning of the humid season, especially in the region south of the country (Fig. 1b, October). In January (Fig. 1c) rainfall occurs everywhere, this is the wettest month and June (Fig. 1d) is the driest month. In consequence, during October rainfall occurs with relatively high values in the extreme south of the country, essentially in Maputo province and coastal belt of Gaza. Meanwhile, in January, the northern region of the country shows higher values of rainfall than the south with exceptions of some semiarid regions of Mecúfi, Memba, Tete, Mungári and Dondo. Rainfall decreases rapidly in the direction to the center and south of the country. The region of the country south of Save iver is very dry in January compared to the center and northern regions. Comparing this region with the some places in the northern region, it shows in January similar values of rainfall amount to those of the semiarid regions of the north. In June rainfall is notably in the coastal belt of Maputo, Gaza and Inhambane and absent in the rest of the country.

Figure 2(a) shows a map were the perceptual deviation of rainfall from the rainfall average (900 mm) in the region is shown. The deviation ranges from –60% to 90%. We can clearly see negative field in the south centered on the parallel of Capricorn and curved due to the effect of the coastal line. This zone includes Gaza, Maputo and Inhambane. In the North of the country we can find some pockets south of Tete and another but small one in the Coastal belt south of Cabo Delgado. Positive values are localized in the remaining areas of the country, with an extraordinary extreme of 90% centered in Milange. All province of Zambézia and the plateau of Lichinga highlights a strong positive deviation.

3.2- The spatial distribution of poverty

Figure 2(b) shows all the places surveyed by the "Inquérito Nacional aos Agregados Familiares Sobre Condições de Vida" conducted in 1996 under the auspices of the Ministry of Plan and Finances, National Directorate of Statistics. We can find that the coverage is very good, but somehow deficient in some remote areas where population density is low and accesses by road is difficult, specially in the interior, in particular certain areas in the provinces of Gaza, Niassa and Tete.

Figure 2(c) shows the spatial distribution of poverty grouped in five shaded categories according to its severity. The different categories of severity results in five equal divisions in the percentual range 0 to 100%. How much clear is the area, how much higher is the percentual value of occurrence of absolute poverty in those places. From the map presented in this figure we find that in general the country is severely affected by poverty, especially in the rural zones. There are some places that are privileged due to their locations, e.g. in urbanized areas and in its immediate periphery. Some zones are apparently benefited from the development of some neighboring countries, such as South Africa and Zimbabwe. Unfortunately other neighboring countries don't show clearly this beneficial effect.

The occurrence of absolute poverty in percentage is, in descending order of incidence and extension, the center of the country (covering the eastern part of the Manica province and all Sofala in the Zambeze Valley); south of the city of Beira, extending from the coast to the interior, and, in low differentiated pockets in a strip around the Tropic of Capricorn such as in areas including Chicualacuala and areas in the direction to the coast covering the interior of Inhambane; a large pocket south of Zambezi river in Tete province, close to the border of Zimbabwe; other pocket to the northeast of the city of Tete in the direction of Angónia; and others South of Gúruè and Southwest of Cuamba.

Cabo Delgado and part of Nampula close to the coastal belt, in the North of the country, displays "better" values. They are relatively better than those previously mentioned places and have similar values as those found in Manica, close to the border of Zimbabwe, and some cities.

There are cities, like the capitals of Sofala (Beira) and Maputo (Maputo) that displays relatively high values of poverty around them.

3.3- Relationship between poverty and rainfall spatial distribution

All rainfall maps, shows a strong similarity with the percentual distribution of poverty. The rainfall derived map presented in Figure 2(a), shows that areas with strong negative deviation located in Gaza interior and southwest of Tete, close to the border of Zimbabwe overlaps with areas with high severity of poverty occurrence. But, we cannot generalize this finding. As we can see some places with good rainfall shows also occurrence of severe poverty.

Comparing Figure 1 that displays the annual normal distribution of rainfall and the normal rainfall distribution in some critical months, with Figure 2(b) that displays the poverty occurrence, it is evident that poverty occurs also where rainfall is abundant.

There is in general a good, but, negative correlation between rainfall and poverty. In some places the country obtains water with certain abundance from rainfall, but we can still find in some of those places high poverty incidence. This shows that population is not only vulnerable to drought but also from excess of water or other factors not discussed herein.

Migration of the rain isopleths from year to year imposes on agriculturalists a risk averse strategy, to reduce or avoid the effects of drought and flood in their activities. This problem challenges meteorologists to produce a better job in forecasting.

It is known, that meteorologists are today making use of non-classical methods of forecasting, sometimes of empiric nature, and are also using local traditional knowledge. Using classical and non-classical approaches during the last years, SARCOF have produced good long-range forecasts in the region.

To fully exploit these results, adequate land use and planning is required. If drought is forecasted, we must be able to use stored water. If excess water is forecasted we must be prepared for flood or to drain waterlogged areas. So, the forecast can be fully exploited if means and infrastructures are available for water management. Hydraulics infrastructures have to be built, and some with a very large dimension. A protocol of water management has to be agreed and enforced at the basin level and between riparian states as a tool to enforce the Kioto Protocol on environmental protection.

These infrastructures and water management systems have been designed and planned in the past to be built. Due to the Mozambican independence and due to the civil war part of those infrastructures haven't been built. These plans have to be pursued and further developed. Some neighboring countries, such as South Africa and Zimbabwe have done a better job in water retention and water management. Mozambique has to catch up the time lost both building infrastructures and developing legal tools for an improved and efficient water management encompassed into a regional and global context.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1- Conclusions

The study found that there is a strong similarity between the normal annual rainfall distribution pattern and the pattern shown by the percentual occurrence of absolute poverty. Poverty abounds where rainfall is scarce and it lessens where rainfall is abundant. But, we still see that many of the areas with good rainfall are very prone to food insecurity and to high levels of poverty occurrence. Considering that all these areas with good rainfall are normally populated with the exception of the high plateau of Niassa that has a low population density, they present a high risk for population loss in case of disaster.

In fact, the actual level of development of the country, have not yet dumped satisfactorily the bad effects of climate on infrastructures, housing, agriculture, industry and population security, among many others.

In general it is found that the country is severely affected by poverty e.g. food shortages, especially in the rural zones. Some cities benefit population that stays around the periphery. But, the large cities of Beira and Maputo show a small beneficial effect to its surroundings. There is a clear and visible discontinuity when we make the transition to the city periphery. Some areas are benefited due to the proximity of a good economical neighbor such as South Africa and Zimbabwe. Almost all the region close to South Africa as a very harsh climate, nevertheless we can see a proximity benefit from South Africa. Benefits can be found in some non-harsh environments in Manica with border with Zimbabwe. Beneficial effects resulting from other countries neighboring Mozambique, other than those illustrated are not visible and therefore cannot be depicted with this study.

4.2. Recommendations

It is proposed that the utility of the natural resources, infrastructures and industries to the populations/communities be effectively evaluated.

We recommend, the establishment of effective institutions and infrastructures to help people in case of disaster. The civil protection unit in the country has to be capacitated and developed in the same fashion as found everywhere in the developed world.

We propose that hydraulics infrastructures for the protection against floods, for the retention and water storage, be developed to face rainfall variability and drought. It is recommended to revise the old proposals that have been made in the past and to launch new ones according to the actual needs. These infrastructures have to be built urgently in the center and north and in some places in Gaza and Inhambane that are severely affected by drought and flood.

We recommend an accelerated development of the peripheral zones surrounding the cities. The inequity of wealth distribution and the difficulty of access to means and resources will produce fluxes of people and pressure in positively discriminated communities.

We recommend the follow up of studies already initiated in the Zambezi Valley prior to the independence that will help the government and the local people to utilize the natural resources for their own benefit.

We recommend the ratification of international protocols on environment, such that of Kioto, and explore the facilities thereafter available to develop programs and projects in the environmental sector.

The factors that can contribute to Mozambican stability are innumerous. But, among those, one is the stability and wealth of our neighbors. The majority of the countries of the hinterland suffer from poverty and slow development and in some case they are moving back or will move back due to very many factors that are today disturbing the region and the humanity. One approach is to strengthen the relationship between the people of the region through an intense cultural, social and economic interchange. To survive any regional unbalance or incapacity, extra regional relationships have to be established and intentionally and strategically supported. This will help to dump local instability.

Regarding to food security, water is the main limitation to food production and to the development of industries and establishment of population nuclei. In this primary analysis we found strong inequality in the natural distribution of water resources resulting from rainfall. In face of this scenario some questions can be put forward. What rights of equality must be enforced between different social groups in the accesses to this resource? How can this right be guaranteed? What kind of development program can we envisage to attain equality and to cope with equality in the difference? How can we start a sound development program in conditions where the country faces high poverty and dependability?

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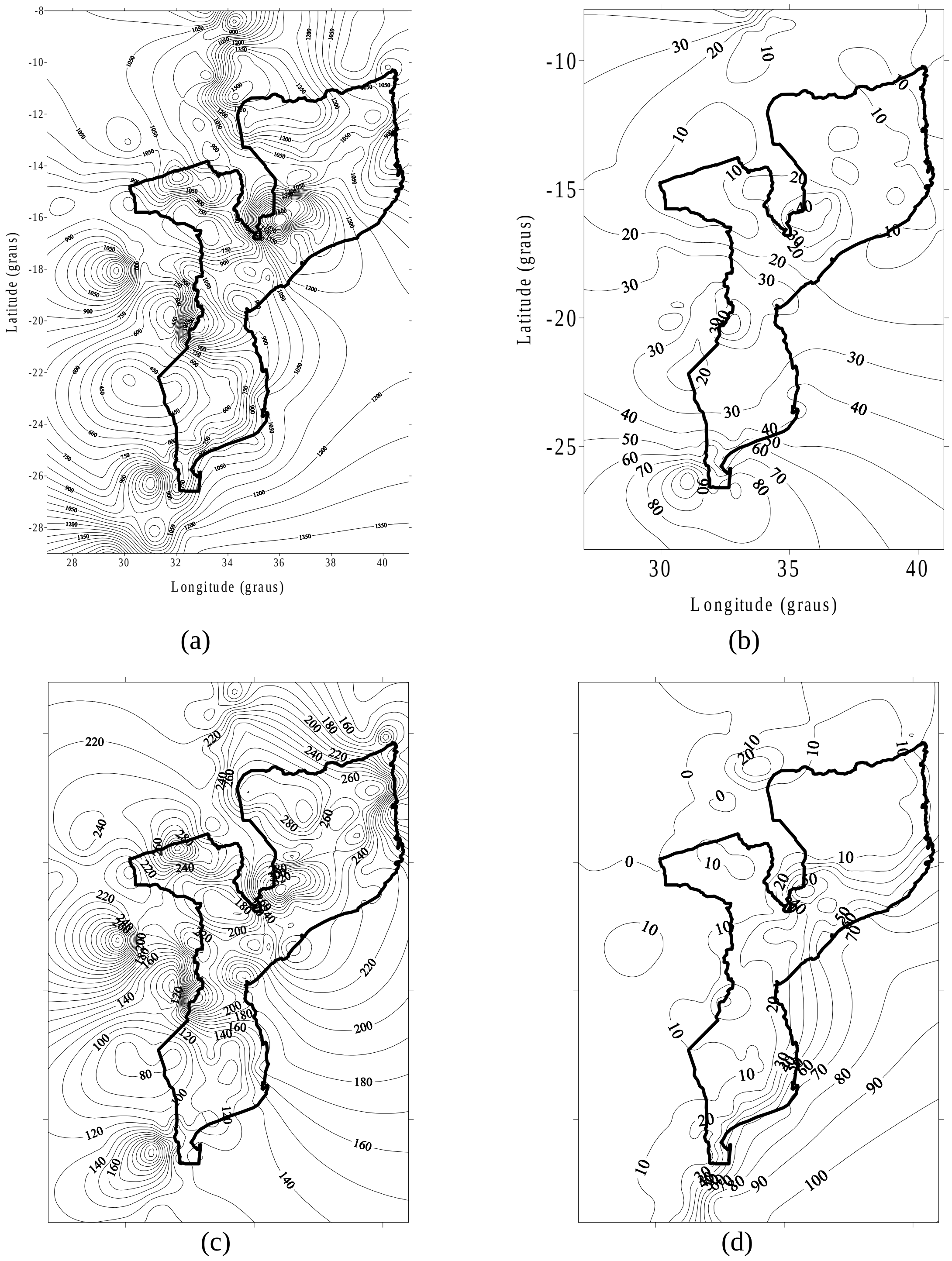

Figure 1 (a,b,c). Top to bottom, maps of normal rainfall (1930-1960) in mm: Annual (a), October (b), January (c) and June (d), interpolated from 164 national and international stations. Source of data: FAO (1984).

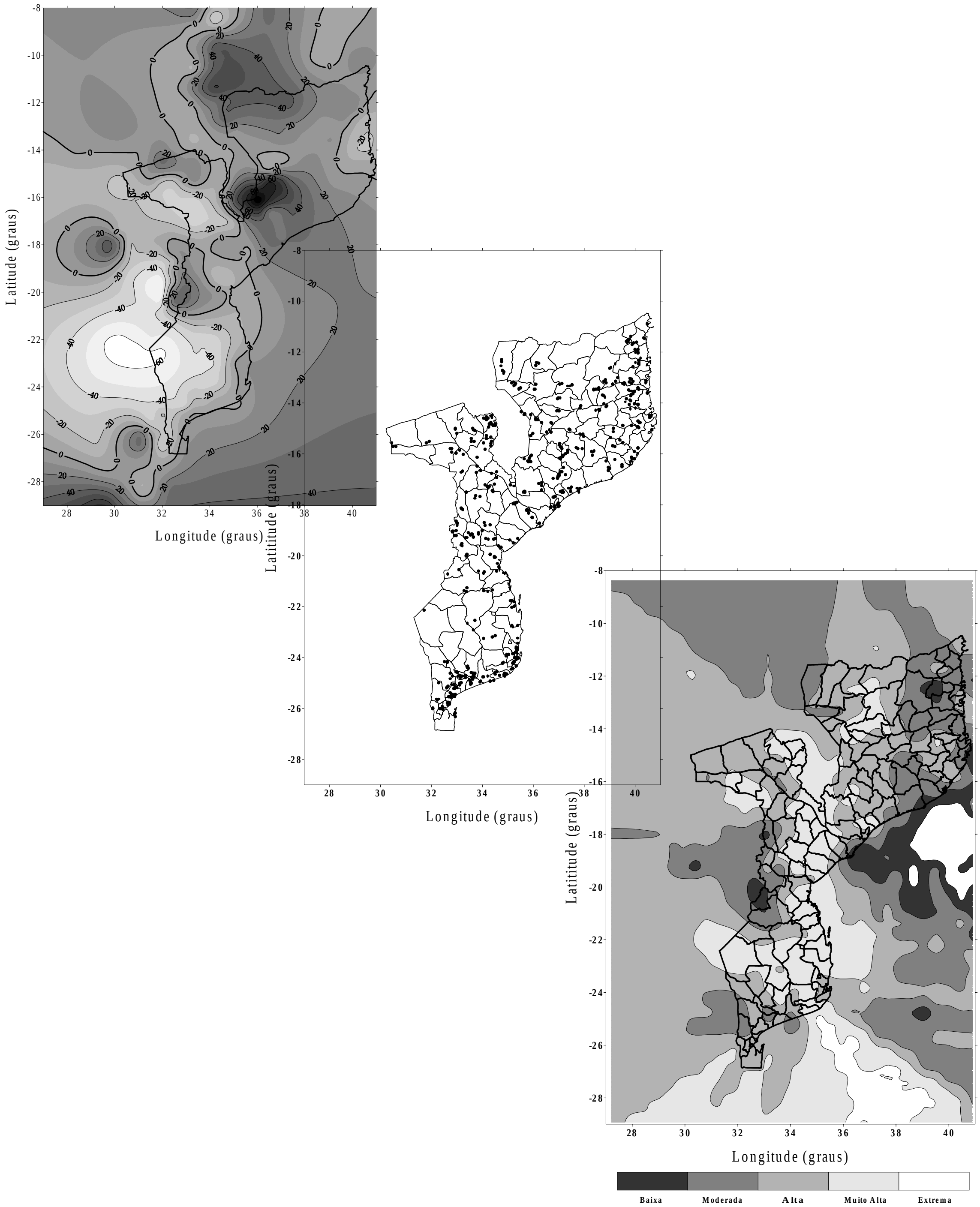

Figure 2(a,b,c). Top to bottom: (a) Map of normal rainfall deviation (%) from the average of the region. Source of data: FAO (1984). (b) **Map** of the places surveyed for the computation of relative incidence of absolute poor people. (c) Map of the relative incidence of absolute poor people. Source of data: Ministry of Planning and Finance (1996).

Operationalising the new Water Act:Contributions from the Save the Sand Project - an integrated catchment management initiative

Sharon POLLARD

Association for Water & Rural Development (AWARD) P.Bag X 483, Acornhoek, South Africa

sharon@award.org.za

ABSTRACT

The Save the Sand Project is a national pilot project for Integrated Catchment Management and Land Care. Catalysed by the 1992 drought, this initiative arose out of a precarious water security situation in the Sand River Catchment in South Africa. In a fundamental departure form the previous water act, the new Water Act (1998) provided the foundation and framework for adopting a new, integrated approach to water resource management. In keeping with the main themes of the act, namely water resource protection, equity amongst users and catchment management, an ecosystems approach has been adopted towards land and water management within the Catchment. These include awareness raising, developmental activities, resource protection measures and rehabilitation initiatives. This paper aims to provide an overview of the key elements of the initiative, as well as to provide a critique of integration as the cornerstone of ICM, in order to provide lessons for the future.

Keywords: *Integrated Water Resource Management; Integrated Catchment Management; Water Act; integrated approaches; Save the Sand Project*

INTRODUCTION

Global attention to sustainable water resource management bears testimony to an increasing sensitivity to water resource issues, certainly at a theoretical scale. Within this context, there has been convergence towards *Integrated Water Resources Management (IWRM)* which is seen as the conceptual framework and tool to mitigate past abuse and to ensure the sustainability of water resources in the future. At a broader scale, a further integrative framework has been that of *Integrated Catchment Management (ICM)* which seeks to recognise the inter-linkages between land and water resources at the catchment scale.

Water crises are predominantly a series of local and regional crises, each with a very different range of problems (Krairapanond & Atkinson 1998). Logically then, whilst ICM may provide the conceptual framework, there is no single approach or solution. In order to have any chance of success these must be, by their very nature, context specific, locally-derived initiatives reflecting the socio-political, economic and environmental realities of the area.

This paper will explore the theme of integration through one such local initiative, based in the Sand River Catchment. This catchment, which lies in the eastern region of the country close to the Mozambique border, has been selected by the Department of Water Affairs and Forestry (DWAF), in collaboration with the Department of Agriculture (DA), as a pilot project for both the design and implementation of an Integrated Catchment Management Plan as well as a lead Land care project. Efforts to reverse the continued degradation of the natural capital of the catchment, coupled with a favourable policy framework that emerged after 1994, led to an initiative that is now known as the *Save the Sand Project*. Some three years down the line, experiences offer an learning opportunity for emerging Catchment Management Fora. First, this paper will briefly examine the concept of ICM, emphasising this approach within the South African context. The second part of the paper will turn to the Save the Sand Project as an example and will examine the challenges of achieving integration, without which the goals of ICM cannot be met.

INTEGRATED CATCHMENT MANAGEMENT [(1)]

Why integrate across a catchment?

The key elements that distinguish ICM from previous water resource management approaches reside on the terms **"integration"** and "**catchment"**. Colloquially the term Integration[(2)] is well understood in that it recognises the linkages between components. Recognising and planning for integration attempts to circumvent *ad hoc* or transient practices that may exacerbate the negative effects of poor practices (and their linkages), whilst fostering those that have mutual benefits. Two key issues circumscribe the concept of integration within the remit of ICM. These are the complex nature of water, coupled with the devolution of responsibility to multiple stakeholders in its management. Thus, integration moves management from the technicist approach to one that is about social processes.

The philosophy of ICM (see Box 1) represents a marked departure from the narrowly focussed management of a single resource such as soil water. This reflects the nature of water which is ultimately an expression, or integrator, of its surrounds. In other words, any activity (be it use or abuse) within an area through which water drains - the catchment- will ultimately be expressed in other parts of the system. For example, erosion caused by poor land-use practices will be felt downstream as increased sedimentation in the river. Recognition of this interconnectedness represents what has now been termed "an ecosystems approach" to resource management.

Most significantly then, ICM represents a systems approach that recognises a catchment as a living ecosystem, consisting of an interlinked web of land, water, vegetation, biota (DWAF & WRC 1996), and people, and the many chemical and biological processes which link these. This reorientation has led to the philosophy that the efficient and sustainable management of water resources can only be undertaken at the catchment scale, irrespective of political boundaries. *Hence, it is inclusive of land-use*, so that all factors and events that impact on the water resources are taken into consideration.

The advantages of using catchments as management units allows managers to formulate a holistic view of interrelated components of an area, the catchment. The overarching principle is that the socio-economic, environmental, institutional and political attributes of a catchment will together construct the characteristics of the catchment, and any change in one or some of these attributes will ultimately be reflected in some or all of these attributes, and ultimately at the scale of the catchment as a whole.

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[1] A comprehensive treatment of ICM has been undertaken by a number of international and local authors (see for example amongst others Dent 1996; Görgens et al.1997; Krairapanond & Atkinson 1998).

[2] The Oxford dictionary offers some standard definitions, with integrate meaning to "combine something in such a way that it becomes fully part of something else", and integrated as "something with various parts fitting together". More interestingly it adds the notion of integration in terms of a human trait as one which is "psychologically stable". Equally, we could lend this analogy to the notion of ICM.

The management of a catchment entails the planning, and operationalising (implementing and monitoring) of activities and approaches to maintain or return the system to a particular state, captured in a catchment plan. It has to focus therefore on both the land and the water resources, and most importantly on their interlinkages. *How* it plans to achieve these is part of the *catchment management strategy*. In its widest sense, ICM recognises the need to integrate all environmental, social and economic issues within a catchment. In keeping with approaches in other fields (Dent 1998), many countries including South Africa, have adopted stakeholder participation as a foundation for integration within the IWRM arena. Thus integration is a key element of ICM[(3)].

ICM in South Africa

The growing complexity of the South African canvas of depleting and degrading water resources, coupled with the pressure to provide water for development whilst ensuring equity and sustainability, provided the catalyst for a new approach to water resource management. In keeping with global policy developments, this approach is underwritten by the key themes of sustainability (economic, social and environmental) and equity. With these as cornerstones, DWAF, as the custodian of the nations water resources, initiated a comprehensive overhaul of the water law, embodied in the National Water Act (Act No. 36 of 1998). This Act provided a set of new imperatives, which focussed on the protection of the river system, and on the goods and services provided by that system (i.e. the resource / people interaction). In a fundamental departure from previous policies, this was embraced in three key elements: Firstly, there could be no private ownership of water. Secondly, it made statutory provision for the *Reserve*, with protection conferred on the water resource base and for water to meet basic human needs. Thirdly, it recognised catchments as the basic unit for water resources management, and makes provision for water resources management in terms of a Catchment Management Strategy (Section 9).

Further support for an ecosystems approach in the Water Act is evident in the principle that "integrated Catchment Management fosters co-operative and consensual techniques to manage water, land and other interdependent attributes of every catchment". Clearly this provides recognition for a people-orientated approach that encompasses the broad range of social processes (e.g. knowledge, collective planning, conflict, co-ordination), and requires that ICM is a process that requires mediation, rather than simply a product.

As stated by Görgens *et al.* (1997) the dynamic and complex nature of the fields of ICM/ IWRM has resulted in inconsistencies in the use and definition of terms [(4)]. South Africa has developed a clear set of definitions (see Box 1), which clearly distinguish *Integrated Water Resources Management* (to achieve equitable access to and sustainable use of water resources), from that of *ICM* (which recognises the inter-linkages between land-use and water resources). Specifically, a number of important principles underpin ICM in South Africa (modified from DWAF & WRC 1996):

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[3] As pointed out by the DWAF & WRC (1996), whilst effective water resource management requires the simultaneous integration of all relevant factors, processes and uses within an system, this does not mean comprehensive, which is an objective that is regarded as too broad to address.

[4] Many approaches to so-called "Catchment Management" exist. For example, "watershed" development projects in India pay insufficient attention to the land-water linkages (Calder 1999). Much of the current initiatives that focus on land-water linkages do not house these under the umbrella of ICM. Rather they are termed Integrated land and water management or Integrated Ecosystems Management (see GEF-STAP)

- **An integrative or systems approach**, which assesses and integrates the links between processes and activities that cause biophysical and ecological changes in catchments;
- **An active partnership approach** so as to achieve outcomes that are understood, and acceptable to all stakeholders and which allow for the sustained use and protection of the water resource.
- **An adaptive management approach** based on a flexible management framework that can respond to changes in information and knowledge (learning by doing).

Box 1: Some definitions
(Gorgens *et al.* 1997; WISA *et al.* 2000)

All the definitions start with: "Simultaneously a philosophy; a process and an implementation strategy to achieve..."

Catchment management: ".. a sustainable balance between utilisation and protection of **water resources** in a catchment. It recognises the need for mutual dependence of water, land use, and aquatic ecology management and for consensual participation by relevant stakeholders, communities and organs of state.".

Integrated Catchment Management: "..a sustainable balance between utilisation and protection of all **environmental resources** in a catchment, and to grow a sustainable society through stakeholder, community and government partnerships in a management process".

Integrated Water Resource Management: ".. equitable access to and sustainable use of water resources by all stakeholders at catchment, regional and international levels, while maintaining the characteristics and integrity of water resources at the catchment scale within agreed limits[(5)]".

Integrated Water Resource Management on a catchment basis: As for IWRM, but at catchment level only.

The principles of ICM have received widespread support in South Africa, but actual implementation is still in its infancy. As yet, no ICM plan under the institutional umbrella of a Catchment Management Agency, has been implemented in South Africa. However, numerous local equivalents exist throughout South Africa which pave the way for providing a model for the development of a catchment plan and a strategy for implementation (e.g. Jewitt *et al.* 2001). One such initiative is the *Save the Sand* Programme, which will be described briefly.

Catalysts for change: The Save the Sand Programme

As stated, the SSP is a national pilot project for ICM and Land Care, supported jointly through the DWAF & DA. It focusses on the Sand River Catchment located in the Northern Province (Figure 1)

It was initiated through local concerns that the ecological integrity, productivity and water resources of the catchment have been severely compromised. These, in turn, precipitated a suite of socio-economic and environmental consequences which have thrown into question the ability of the catchment to support its residents and which highlighted the lack of resilience of the system in times of stress. This situation is exacerbated by the homeland legacies of Gazankulu and Lebowa, evident in extremely high densities of people with limited access to arable land and water resources. Furthermore, gross inequities in access to water for the rural poor in comparison to other sectors such as agriculture and forestry, exist.

[5] IWRM is clearly seen as a subset of ICM focussing on just the water resources of the catchment

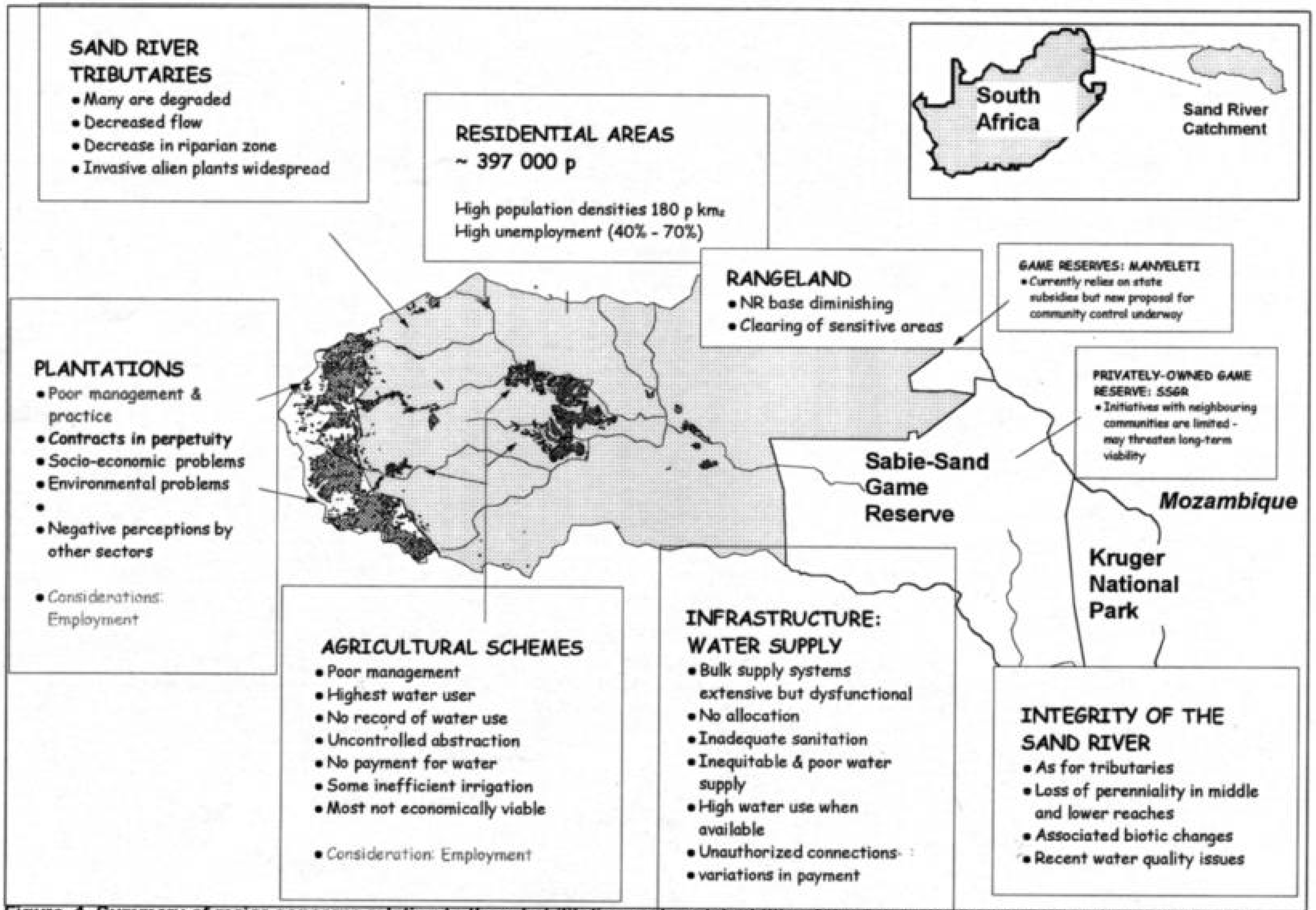

Figure 1 Summary of major concerns relating to the rehabilitation and sustainability of the Sand River Catchment (Pollard et al. 1998)

The vulnerability of the catchment was evidenced during the protracted drought of 1992, which demonstrated that water security was of particular concern. During this period, conflict regarding water use came to a head with no apparent mechanisms, or framework, within which to address this. Inequities were evidenced in the continued supply of water to crops whilst water had to be trucked into the catchment to meet basic human needs, sometimes as low as $10\ l\ c^{-1}d^{-1}$. One of the main revenue earners of the catchment, and a downstream land-owner, the Sabie-Sand Game Reserve, was confronted with a river system that was unable to support the game which it marketed for the tourist industry. Blame was laid squarely on the shoulders of upstream users, forestry and agriculture. The lobbying efforts increased, formally by the private sector and less formally through the increasing demands of the rural poor. Fortunately, under the stewardship of a new minister within DWAF, a climate emerged that was conducive to addressing past inequalities and that encouraged real sustainable natural resource management (see previous discussions).

Given these growing concerns, a feasibility study was commissioned by the DWAF and DALA, to explore appropriate means to secure the longterm natural capital of the area through an ICM approach. At the same time the promulgation of the national Water Act (1998) provided the supporting regulatory and policy framework for the SSP.

Overall approach

The overall approach to the SSP is summarised in Figure 2. The essential elements are Phase I: Ecosystem evaluation and Phase II: Implementation and Monitoring.

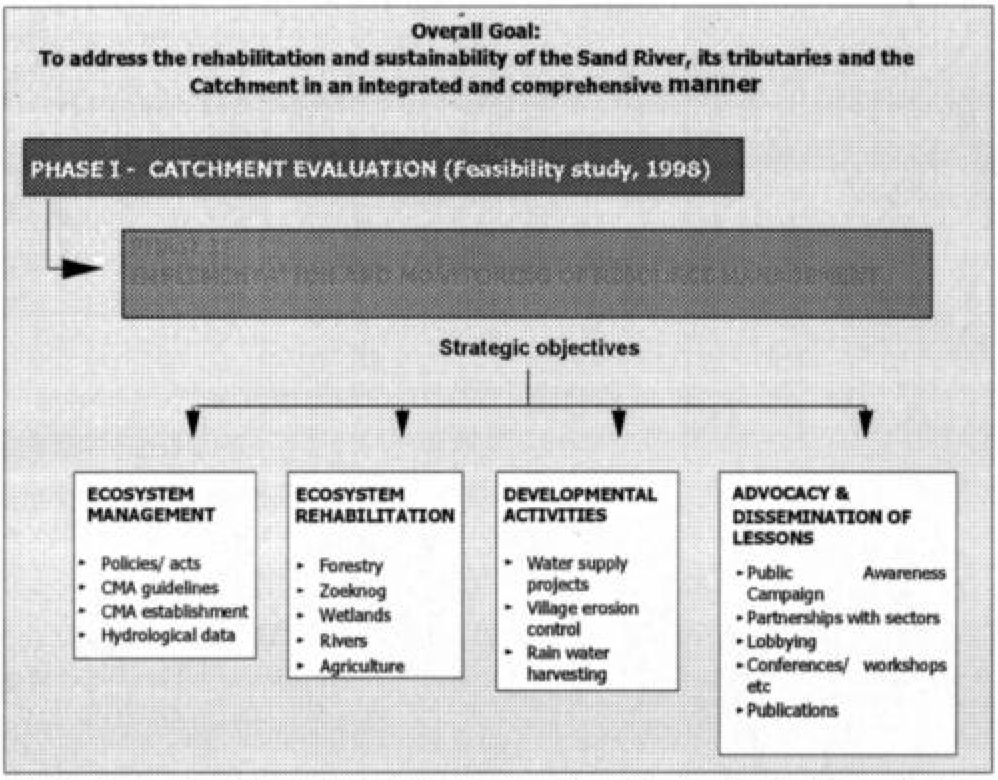

Figure 2: An overview of the Save the Sand Programme indicating the overall goal, phases and main objectives.

PHASE 1- The planning process: Ecosystem evaluation

Essentially, the ecosystem evaluation comprised the feasibility study (Pollard *et al.* 1998). The objectives of this study were to embrace the conceptualisation, consultation and planning of the proposed project, guided by the key objectives, of (i) Rehabilitation and sustainability; (ii) Equity and (iii) Economic growth.

The key steps involved (i) a description of the status quo with regard to water and land, both in terms of their availability and use practices; (ii) an assessment of these according to socio-economic, environmental and technical criteria (summarised in Figure 1) and; (iii) the development of a suite of recommendations and proposals. In addition, scenario-based planning was conducted in order to develop and evaluate possible future land and water-use scenarios and their impacts on water resources (see Joubert & Pollard in prep). This last step offered the opportunity to integrate the wide range of recommendations into a coherent vision for land-use. In addition to these were a number of proposals related to river management, alien vegetation, awareness raising and stakeholder participation, and institutional structures.

Phase II: Implementation and monitoring

Based on the findings of the feasibility study, implementation of the various components of the SSP started in February 1999, under the guidance of a steering committee[(6)]. Key recommendations from the feasibility study formed the objectives under the overall goal of “addressing the rehabilitation and sustainability of the Sand River, its tributaries and the catchment in an integrated and comprehensive manner”.

A series of interventions were designed for implementation under each objective, and then prioritised and ratified by the stakeholder steering committee. Although there are cross-cutting elements throughout the programme, these can be broadly categorised under four main strategic objectives or areas of work (see Figure 2):

(i) developments in the external policy environment regarding Ecosystem Management;
(ii) awareness-raising and dissemination of activities,
(iii) developmental activities and,
(iv) rehabilitation initiatives.

The interventions are truly multi-sectoral and include integration with the overall national policy initiatives, such as the establishment of Catchment Management Agencies, an extensive public awareness campaign, improved domestic water supply, land rehabilitation measures including erosion control, rainwater harvesting, and the removal of alien vegetation (including mature plantations of exotic trees), mainly in the upper catchment area. As stated, these objectives should not be seen as statically defined units with no overlap. Despite the usefulness of this approach for planning purposes, most

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[6] Under the SSP, the activities of a number of agencies in the catchment area have been co-ordinated through a steering committee. These include the DWAF, and the Working for Water Programme, the private sector (through the Sabie-Sand Wildtuin); the Northern Province Department of Agriculture (NPDA) and local government (water-desk councillor) as well as other interested parties. The Steering Committee, meets once every three months to review progress, to exchange information, to prioritise and approve work programmes for the coming quarter and to resolve policy issues as they arise.

activities under each objective have elements of the other strategic objectives and this is particularly true of the awareness campaign. For example, based on the principle of learning through action, the development of rainwater collection initiatives has a strong developmental element but, equally, are being used as an entry point for awareness raising regarding both the SSP and rainwater collection.

The SSP signified some key shifts in thinking. Most notably, this has been to re-orientate activities and collaboration under the remit of ICM, which in effect, has provided the strategic direction. This has required extensive internal rationalisation: A key strategic philosophy that the programme tried to capture was that of the “wise use of water”. Prior to turning to costly, technical solutions to mitigate diminishing water resources, we had to be sure that the water that was currently available was being used as wisely and appropriately as possibly. There is little rationale behind investing large amounts of capital in structures such as dams, (and suffering their costs) if the available water was being used by a sector in an unsustainable way, at huge environmental costs, with little socio-economic benefits. To put it simply, some internal “house-keeping” was necessary, if the departmental mission “some for all, forever” was to be realised. Long the turf of engineers and planners, this requires the inputs a far more diverse group of professionals and stakeholders, and raises the profile of integration through co-operative governance.

Achieving integration within Catchment Management approaches

Although the concept of ICM had been recognised by DWAF since the 1980s, it was only with the advent of the new government in 1994 that important elements such as integration and stakeholder participation were given real effect. Under apartheid planning, for example, just the challenge alone of trying to achieve integration across the spectre of so-called “political boundaries” created by homeland policies was all but nearly impossible to achieve.

Given this history, certain key questions must be asked within the remit of ICM/ IWRM,: why seek integration; and what does integration require? The former question has already been addressed under the philosophy of ICM which recognises the intimate connection between land and water. Thus, for their development to be sustainable, management must be integrated through co-operative approaches, which brings us to the second question.

Finding a coherent answer to the question, “what does integration require?, is more demanding given the lack of practical experiences of successful integration. The theoretical framework, which identifies key preconditions for integration, has been well documented. Broadly, these include a supportive and integrated policy framework, as well as the additional elements mentioned earlier including a systems approach, the development of partnerships (stakeholder participation, the development of a common vision, collaborative planning) and adaptive management.

Whilst the policy environment may well have changed in South Africa, achieving an integrated approach to water resource management remains a challenge. This is because integration still relies heavily on principles espoused in the Constitution rather than in a truly integrated policy framework. In reality, DWAF, as the national agency responsible for water resource management has little control over landuse activities, with the exception of forestry, mining and solid waste disposal (see Görgens *et al.* 1997). The diversity of institutional competencies coupled with the range of regulatory tools for land-use management (Box 2), highlight the complexities of the integration challenge. Thus, in reality, the notion of integration (not only IWRM) rests heavily on the principle of co-operative governance and stakeholder participation as elaborated in the Constitution (Act 108 of 1996; WISA *et al.* 2000).

Box 2 Some regulatory tools governing water and land use in South Africa

WATER:

National Water Act (Act 36 of 1998):

See previous discussions. Promotes water management at a localised level. Requires that CMAs be established, and that these develop Catchment Management Strategies

Water Services Act (Act 108 of 1997):

Provides that Water Service Development Plans be developed by Local Authorities. May be part of Integrated Development Plans (see below)

LAND:

National Environmental Management Act (Act 107 1998):

Provides for co-operative governance in matters affecting the environment. Statutory requirement for the development of Environmental Implementation Plans & Environmental Management Plans for environmental resource management. Also addresses environmental management agreements between government and the private sector.

Development Facilitation Act (Act 67 of 1995):

Launched by Dept. of Land Affairs to provide a framework for land development. Requires all Local Authorities to develop Land Development Objectives (LDO), which are high level approaches to long term spatial planning

Department of Constitutional Development requires Local Government to develop Integrated Development Plans (IDP), includes management plans (and budgets) of LG activities. Should also include an Integrated Development Strategy.

Within the water resources sector, the vehicle for institutional and stakeholder integration is seen to be through CMA (or Catchment Management Fora) and through regulation (WISA *et al.* 2000). Practically, the issue remains: will this institutional structure be able to effect changes in landuse practices to achieve better water resource management? And, how might this be sustained?

Integration is about behaviour changes which is sought through social processes, in the South African context (i.e. participation). These two preconditions for ICM are intimately linked in that integration requires participation which, in turn, requires knowledge of and judgements regarding risk-value systems. In other words, in order to effect behaviour changes, not only do participants need to understand the status quo, its problems and challenges from multiple perspectives but they also need to develop a common set of objectives, through consensus, for the future. This requires that stakeholders are equipped with conceptual capital of why and *how* this should happen, as well as the benefits and costs of change. Notwithstanding the promotion of the concept of participation, few practical examples of successful *integration* exist. For example, despite adequate skills and resources in Australia, salinisation has increased and remains a perennial problem (Calder 1999).

In the Sand River Catchment, the SSP has acted as a facilitator for co-operative governance, and promoting integration has been a clear objective. A number of examples that illustrate the complexities of integration exist. The first pertains to the issue of appropriate land-use in the upper catchment, which relied heavily on the development of partnerships. As the custodian of the land, DWAF had limited resources to address the extensive degradation of sensitive areas through poor management practices. To address this a collaborative approach was adopted between the Department of Agriculture (though the Land Care programme) and Working for Water. Together, these partners have rehabilitated key wetlands, removed extensive stands of alien vegetation and stabilised points of extreme erosion. More recently, the Department of Environmental Affairs and Tourism has entered the partnership in order to explore alternative longterm landuse plans for the upper catchment. These partnerships were fostered through senior departmental staff and facilitated through champions.
Nonetheless, at another level, attempts to achieve integrated planning using the SSP steering committee as a vehicle, provides with little evidence of co-operative governance. This has played out as sectoral propriety with, for example, provincial departments seeing land-use and planning processes

as their “turf” - in a way that is seemingly divorced from the need or benefits of integration. Waving the “constitutional flag” of responsibilities does little to foster a spirit of co-operation in reality, and other means must be sought. In part this is also due to the extreme pressures on staff and capacities (“change is costly” seems to be the implicit message). Currently, for example, the Department of Agriculture is attempting to deal with the extensive numbers of former homeland agricultural schemes, which are all on the brink of collapse. With strategic planning underway, coupled with the institutional and operational uncertainty that characterises their future, implementing water and soil conservation measures under the banner of ICM is a daunting task. Finally, as a lead agent, it has been stated that DWAF needs to interlink policies and guidelines of other departments (WISA *et al* 2000), but this type of initiative is either not being undertaken or awareness does not appear to be filtering through the various spheres of government.

Even within the policy framework of one department, such as DWAF, achieving real integration through co-operation will remain a challenge. For example, the management of water resources is governed by the Water Act (1998) and falls under the custodianship of the CMA. In the case of the Sand River, this will fall under the Inkomati Catchment Management Agency. Water supply, on the other hand, is governed by the Water Services Act (1997), undertaken by the local authority on a district boundary. In the case of the SSP, part of the Sand River Catchment falls within the Eastern District Council, which straddles both the Inkomati and Olifants Water Management Areas. Clearly, the catchment boundaries are not coincident with the administrative boundaries and hence, achieving harmony between water resource management and water supply requires added collaborative efforts. Already Local Government is developing Water Service Development Plans that rely on water resources from two different catchments, but this appears to be taking place in isolation of the CMA proposals, or with little mediation from the regional departments. Although the SSP is undertaking an intensive initiative to raise this issue, it relies on the collaboration of multiple stakeholders who can, seemingly, operate in the relative sanctity of isolation.

Having raised some key concerns, it is important to bear in mind appropriate time scales. The shorterm objective of the CMS is to achieve IWRM in catchments. This is a component of ICM which is the longterm vision (WISA *et al.* 2000). Therefore, an additional, and possibly the most important precondition of integration, is one of developing a phased approach. This recognises that people-centred processes are time consuming but, in the longer term, are more likely to lead to sustainability. In this regard, it is important to note that future generations are one of the key stakeholders in the arena of ICM and identifying future needs is no easy task.

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"All for some": Zambian & Zimbabwean case studies on inequitable access to water

Peter B. ROBINSON

Principal, Zimconsult
P O Box A228, Avondale, Harare, Zimbabwe

robinson@icon.co.zw

ABSTRACT

In many situations in Southern Africa, those with access to water become vociferous proponents of low tariffs. The majority who do not have access to water, are a large, voiceless group without corresponding profile and political influence. For the supply authorities, sub-economic tariffs mean insufficient revenue for operations and maintenance and no resources for expanding the system. Those with access and sub-economic tariffs effectively preclude others from being supplied with water.

These themes are explored in this paper in the context of two case studies – urban water supply in Zambia and small-scale irrigation schemes in rural Zimbabwe. The analysis leads to a discussion of broader issues of economic development and poverty alleviation.

Keywords: *equity; access to water; productive water; poverty reduction*

1. INEQUITABLE ACCESS

Disparities in access to water are all too evident in both urban and rural areas in southern African countries. High income urban households have treated water piped into their homes, typically at sub-economic prices, with the result that lavish use is made of water not just for basic requirement but for gardens, swimming pools and washing cars. At the other end of the spectrum, poor households on the margins of urban areas have scant access to water, often having to scavenge and carry water over long distances just to meet basic needs. Where informal water vending has arisen, the price per litre is typically much higher than the price paid by the connected consumer. Similarly in the rural areas, large-scale commercial farmers have access to irrigation water which makes it possible for them to insulate themselves from droughts and to produce much higher value crops than subsistence farmers forced to rely on rain-fed cropping.

At first gloss, the existence of these disparities in access to water might be interpreted as a reflection of general underdevelopment, the countries being unable to raise the investment resources to extend water provision to all. This viewpoint is rather superficial, however. The roots of underdevelopment in respect of water are inappropriate macro-economic and sectoral policies. The special status of water – which results in water being treated as a right and as a catalyst for development – obfuscates its dual role as an economic good. Zero or very low tariffs, which are justified as being consistent with water's special status, in fact serve to undermine any programme of making water accessible to all (making real the notion of water as a 'right'). This leads to a narrowing of development options, resulting in exclusivist rather than inclusivist development, and stagnation rather than dynamism.

Through exploring case studies from Zambia and Zimbabwe, the paper seeks to identify and explain the political interest group dynamics which perpetuate inequitable access to water and, in so doing, limit national development potential.

2. URBAN WATER CASE STUDY - ZAMBIA

Zambia's *National Water Policy* identifies the main objective of the water sector as being the promotion of "sustainable water resources development to facilitate equitable provision of an adequate quantity and quality of water for all competing groups of users at acceptable costs, while ensuring security of supply under varying conditions". At the time of this statement (1994) urban water supplies were acknowledged to be neither sustainable nor equitable and improving urban water provision became the first target of water sector reforms. A new *Water Supply and Sanitation Act* was passed in 1997, water and sanitation responsibilities were removed from the councils and municipalities and given to 'commercialised utilities' [CUs] which were formed in the major urban centres and a professional regulatory body, the National Water & Sanitation Supply Council [NAWASCO], was established[1].

Zambia's urban areas are typified by a sharp divide between the fully planned and established areas and the so-called 'peri-urban' areas which have arisen as the result of unplanned and unauthorised informal settlement. While the former are served by reticulated water supplies and water borne sewerage systems, the latter have a mix of communal standpipes, point sources of water (shallow wells, boreholes etc) and drawing of water from rivers and streams, with various types of latrines for sanitation. The poor standards and low level of coverage in the peri-urban areas reflects the earlier reaction of the authorities, which was to condemn such settlements as illegal. With a change to recognising the permanence of the peri-urban zones and the promulgation of a policy of equity, there is a large gap to be filled. On government own figures, "about 70 per cent of the urban population has access to piped water. However, there are serious deficiencies in peri-urban areas and informal settlements, where at least 56 per cent of the population do not have access to safe water supply and as much as 90 per cent do not have access to satisfactory sanitation facilities"[2].

Even within the areas where piped household connections are the norm, quality and reliability of service had deteriorated markedly in the period before the CUs were formed. The municipalities and councils lacked the resources and the management skills to properly operate and maintain the water and sewerage systems, resulting in continuous deterioration in the infrastructure, high levels of losses and frequent disease outbreaks when water was inadequately treated due to shortages of chemicals. Based on notions of 'water is life' and hence access to water being a human right, urban water and sewerage tariffs had always been low. It became progressively more difficult, however, for tariffs to be raised. As long as service provision was inefficient and unreliable, those with household connections were understandably hostile to tariff increases, but without higher revenues it was difficult for councils to begin to improve things, let alone start investing in the peri-urban areas to improve the situation of those without access to clean water.

The culture of low tariffs was sustained by populist political positions adopted at the national level. With it being invidious for councils to increase tariffs, the alternative mechanism for raising revenues was to opt for high levels of consumption. The environment thus created had the effect of encouraging habits of profligate use of water, which when combined with lack of maintenance of plumbing installations, leading in some cases to continuously running standpipes, resulted in some of the world's highest levels of apparent water consumption. Per capita water usage in Zambia has been calculated to be 3 to 4 times per capita levels in Europe and 6 times those in West

[1] In forming the CUs, the chronically non-viable water and sanitation departments in Zambia were removed from the urban councils and this served to improve the financial position of urban councils. In Zimbabwe's case, water and sanitation departments have traditionally made a positive contribution to council finances, so that moves to form commercialised utilities (in part to ensure that tariff revenues are used only for water and sanitation purposes) would have to be preceded by finding alternative sources of revenues to cover council costs normally cross-subsidised from the water and sanitation account.

[2] From speech by Hon Dr Katele Kalumba, Minister of Finance & Economic Development to 12th Consultative Group Meeting, Lusaka, July 2000.

Africa. Rather than tackling demand management to achieve levels of consumption which would have some chance of being met from existing installed capacity, Zambia has gone ahead with hugely expensive supply augmentation schemes which compound rather than solve the underlying problems[3].

The approach of the government, with the support of various donors, to the establishment of the CUs has largely been to rehabilitate the basic supply infrastructure to restore the expected level of service to those with household connections, while maintaining some of the main elements of the old system, in particular low levels of tariffs which do not even cover basic operation and maintenance costs, let alone make provision for expansion. While the notion of commercialised utilities operating under an independent water sector regulator is commendable, the CUs so far have been saddled with a number of problems which make it impossible for them to operate in a 'commercial' fashion, namely a large shortfall between revenues and operating costs, lack of working capital, inherited liabilities, public sector debtors and secondment of all staff from what were previously grossly over-manned water and sanitation departments of councils.

In such circumstances, very little has been done by the CUs to improve water and sanitation provision in the peri-urban areas. Various donors have initiated 'community based' projects in these areas, so far with varying outcomes. The approach of trying to transfer rural community participation concepts to the urban areas is problematic, particularly in technologies such as water vending from standpipes where the basic supply infrastructure is part of the CU's system, so that ultimate operation and maintenance responsibility in fact lies with the CU. If and when the constraints presently inhibiting the CUs have been removed and they are given the opportunity to strengthen themselves, they would then be in a position to provide proper levels of assistance and support to make the peri-urban projects operate satisfactorily on a sustainable basis.

One of the major donors promoting projects in Zambia's peri-urban areas has established four basic principles which should be applied in urban water and sanitation[4]:

(1) Access to water and sanitation services for ALL within a town and its highly populated adjacent areas.

(2) Low income groups should not pay more for services than connected households – benefits of economies of scale for all within a service area, implying affordable, different technologies for different consumer groups according to ability to pay.

(3) Sustainability of service provision – total cost recovery within the system, allowing at the same time for lifeline tariffs, this implying sufficient cross-subsidisation from large consumers to the poor and low income areas, but equally no service should be free of charge.

(4) Minimum service levels for all – regardless of income area or technology used, the providers should guarantee a minimum service to all consumers, particularly on water quality, supply hours at connections and kiosks, and standards for sanitation.

Based on successful experience in Burkina Faso, these principles should not be unattainable in a Zambian context, but there is a long way to go. Indeed, given that at present access to adequate

[3] The $20 million Kitwe supply expansion project currently being implemented falls into this category. The phenomenon of urban councils having perverse incentives to encourage profligate use of water is also very evident in Zimbabwe, where the costs of new sources of supply (dams and pipeline systems) that are deemed to be needed to meet inflated water demand are becoming hugely expensive (this being because most of Zimbabwe's urban areas are on a watershed, with new dam sites being ever further away from the urban centres).
[4] Drawn from Werchota (2001).

water and sanitation in Zambia's urban areas is highly skewed and that the poor are paying prices for water at kiosks which are as much as 10 times the unit price of water for a connected household, attainment of these principles represents a major challenge. Meeting this challenge will require overcoming the huge resistance which connected consumers have to paying higher tariffs, by both improving service delivery and meeting the needs of the broader community in a transparent and clearly cost-effective manner. The resulting structure would, however, go a long way to improving the health and general standard of living of poor urban households, while at the same time addressing poverty more directly by making possible the expansion of remunerative activities in the peri-urban areas which require water as an input to the production processes.

3. RURAL WATER CASE STUDY - ZIMBABWE

In 1999, the author was involved in a study on the necessity for the continuation of subsidies to small-scale irrigation schemes in Zimbabwe[5]. At the time, the rural population (outside of large-scale commercial farms) was around 6,6 million or about 1 million households. The total number of families on smallholder irrigation schemes amounted to about 20 000, or just 2% of the total. Given that the promotion of smallholder irrigation schemes has been one of the key policies of the post-colonial government to improve the productive base of rural people, giving only 2% of the population access to such schemes (some of which were established before 1980) 20 years after independence can only be regarded as abysmal. The high level of government extension effort and direct subsidies which had in the past gone into smallholder irrigation schemes might have been justified if these schemes had proved themselves to be unambiguously viable and successful for the farmers involved. Unfortunately, this was not the case. While a few schemes were providing participants with reasonable levels of income, many others were floundering.

Institutionally, the schemes were managed by the Department of Agricultural, Technical & Extension Services [AGRITEX], which was responsible for agricultural extension and maintenance and repair of in-field works. The Department of Water, however, was responsible for the maintenance of the dams and, for all schemes which did not involve gravity feed, for the pumping of water (electricity or diesel costs as well as maintenance requirements). Up to 1995, the plotholders had been levied only a flat fee (Z$145 per hectare per annum), representing some degree of recovery of AGRITEX expenses. After 1995, the Department of Water sought to impose a water charge on plotholders. Being based on the national average 'blend price' for agricultural water, this charge was not related to the costs of the scheme, irrigators with gravity feed paying the same as their counterparts receiving pumped water[6]. As prices of electricity and liquid fuels were adjusted nationally to economic levels, the difference in costs for the Department of Water between pumped and non-pumped schemes grew exponentially.

As of 1999, the size of the recurrent subsidy to the small-scale irrigation schemes was estimated at between Z$3000 per ha (for a gravity scheme) and Z$6000 per hectare for a pumped scheme, with the average subsidy amounting to Z$2100 per plotholder, of the same order of magnitude as net returns to less efficient plotholders. The total annual subsidy of Z$42 million needs to be compared with the revenue supposed to be raised from plotholders (Z$16,5 million, if there was 100% collection) and the budget allocations for smallholder schemes (Z$4 million for AGRITEX and Z$7.2 million for Department of Water)[7]. With budgetary allocations way below requirements, water delivery to the schemes became increasingly unreliable at the same time that plotholders were being required to pay much more than they had been used to paying, leading to understandable anger and resentment.

[5] Zimconsult (1999).
[6] A critique of the blend price system is given in Robinson (1999).
[7] Zimconsult (1999), pages 43-44. The calculations were complicated by different de facto water pricing policies being applied in different policies.

Under pressure from plotholders, it was AGRITEX officials who were vociferous in arguing for the continuation of subsidies. Without continued recurrent subsidies, particularly in the pumped schemes, fears were expressed that production would become completely non-viable, leading to the irrigation schemes being abandoned, plotholders returning to rain-fed subsistence agriculture and the considerable national capital investment in the schemes going to waste. This line of argument for the continuation of subsidies was weak on two counts:

(a) unwillingness to acknowledge that formal irrigation schemes should and could be made more productive by a change in crop mix;

(b) lack of appreciation of the opportunity cost and poverty intensification implications of continuing to subsidise a small proportion of the rural population while the majority were deprived of access to productive water.

On the first point, most of the small-scale schemes were producing low value basic food items (maize, beans, tomatoes, green vegetables). Much of the produce was used for home consumption, although some was being sold in markets in urban centres accessible by bus or else being sold in bulk to canning companies. Very few schemes were involved in producing high value crops for markets further afield, but such crops could have provided the levels of value added required to justify the large capital investments incurred in establishing the formal irrigation schemes. AGRITEX has traditionally had the role of assisting farmers with producing the crops that the farmer had chosen to produce, rather than assisting with the more fundamental issue of identifying markets and adjusting the crop mix so as to maximise the farmer's financial returns for her efforts, and in the process achieving the levels of viability in the small-scale schemes which would justify the sunk investment costs. Some of the provincial officers interviewed were adamant that AGRITEX's should continue only to focus on production, while at the scheme level more progressive AGRITEX cadres had demonstrated the feasibility and the financial rewards of plotholders moving to high value non-traditional crops such as paprika.

On the second point, hostility was also encountered to the suggestion that government should broaden the range of technologies and options which it promotes. Despite it being clearly more equitable to provide some form of water supply through simple technologies (such as dambos, wells, boreholes and collector wells) to a large number of beneficiaries than it would be to provide opportunities for a small number of irrigators on formal schemes, some officials maintained that to give 'second grade' technology to small-scale irrigators would not be acceptable. The economics, however, point in quite the opposite direction, with the difference in investment costs between simple technologies and formal irrigation schemes differing by a factor as large as 25, and an even larger recurrent cost differential. Nonetheless, the study revealed (surprisingly) that it is likely that the low technology households can realise commensurate or even higher levels of net incomes, with greater reliability, than their counterparts on formal irrigation schemes.

This was found particularly to be the case where farmers had become involved in producing horticultural products for export, a growing trend outside of the small-scale irrigation schemes, by 1999 involving an estimated 6 000 communal farmer households (equivalent to 30% of the total number of plotholders on formal irrigation schemes). The marketing companies reported a preference for contracting individuals over groups and communal farmers over plotholders, because the farmers using the simplest of technologies (drawing water in buckets from wells) were found to be more reliable than the plotholders, where uncertainty about water supplies often disrupted production schedules. A small improvement in water extraction technology (such as a rope and washer pump, making it possible to water a larger area with a hosepipe rather than hand watering with buckets) would greatly increase income generating potential at a very small investment cost (Z$3000 in 1999) and negligible recurrent costs. While most of the small-scale produce exported at that time was perishable products such as mange-tout, baby corn and sweetcorn, all produced within a reasonable distance of Harare International Airport, less perishable products, such as paprika and granadillas would be more feasible, but still lucrative, on schemes which are in more distant parts of the country. Other high value non-perishable products in which small-scale producers should have a distinct comparative advantage would be the specialist production of seeds.

This case study vividly illustrates the political imbalances which serve to perpetuate inequitable access to water. The 2% who are members of the formal small-scale irrigation schemes form visible, close-knit groups across the country able to put pressure on the system at the national level through persuading AGRITEX to articulate their concerns and interests. The unserved majority (98% of communal households) have no identity and no agency to identify and voice their concerns. Concepts such as the primacy of marketing over production, irrigation technology choices being inappropriate, subsidies unjustified and options for the majority thus being forfeited, are too abstruse to be readily grasped, let alone turned into an agenda for change. This has enabled the post-independence government to get away with a narrow, patronage-based form of development, ignoring land reform and doing very little about access to water until challenged politically in the year 2000, and then abusing the issue.

4. CONCLUSIONS

The epoch of socialism in Zambia and Zimbabwe was expected to lead to an equitable pattern of growth, but in fact served to entrench patterns of exclusivist development. This is nowhere more clear than in respect of water, where in both Zambia's urban areas and Zimbabwe's rural areas relatively small groups have had access to high levels of service and have in the past been in a position to petition successfully for continuation of explicit or implicit subsidies. Resources to extend similar levels of service to the majority have not been available, and the inequities have grown more pronounced. As structural adjustment has forced greater financial stringency, inadequate water tariffs and the resulting financial crisis in the supply systems have provoked periodic review and adjustment. What is needed now in both countries are governments committed to fundamental change involving a re-orientation to inclusive development.

In that regard, the principles for urban water supply enunciated in Section 2 are key. They constitute a vision for urban water which requires that there be affordable access to clean water and satisfactory sanitation for all, with sufficient cross-subsidies in the system so that the poor do not pay more per unit than the rich, and that all water be efficiently used and paid for so that the system is sustainable. Implementing these principles will require a careful mix of technologies to be adopted for service delivery. The kiosk systems presently being piloted in Zambia's peri-urban areas would appear to have considerable potential provided the commercialised utilities are put on proper footing. As things stand at present, the imposed weaknesses of the CUs could easily result in irregular supplies to the kiosk systems and a lack of the sort of back-up and support needed to make the concept flourish.
Greater openness to technological options also emerged as important in the rural case study. In Zimbabwe and other countries in the region there is a wide range of technologies which can provide water for productive purposes at relatively low costs, the options including:

- gravity-fed formal irrigation schemes;
- collector wells;
- boreholes and deep wells;
- hydraulic ram pumps;

- hand pumps for sand extraction and water from shallow wells[8].

What is technically, socially and economically appropriate in one setting may not be in another. A flexible approach, where a wide range of options is considered before projects are finalised, is needed to make the best use of available possibilities. The technology needs to be chosen not just on technical merits, but crucially in relation to the marketing opportunities available. By starting with exploring demand and marketing possibilities for different crops and then providing assistance with the production requirements, even households with the simplest water technologies can obtain the opportunity to raise incomes from their labours to more reasonable levels. What is being advocated is a diversity of water projects, not excluding large irrigation projects, but focusing on a range of technologies and market opportunities targeted at the mass of the population. Taking this approach seriously would constitute a major step towards effective and sustainable poverty reduction in southern Africa.

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[8] A large number of NGOs in the sector have demonstrated the feasibility and viability of alternative water technologies (which they have also developed and refined), but no country has grasped the nettle of trying to deploy such technologies in national programmes.

Rainwater management for increased productivity among small-holder farmers in drought prone environments

Johan Rockström[1], Jennie Barron[2] and Patrick Fox[2]

[1]IHE-Delft, PO Box 3015, 2601 DA Delft, the Netherlands
[2]Dept. of Systems Ecology, Stockholm University, 10691 Stockholm, Sweden

jro@ihe.nl

ABSTRACT

A critical analysis of conventional water resources assessments and re-visiting the on-farm water balance suggests large scopes for water productivity improvements in smallholder rainfed farming systems in drought prone environments of Eastern and Southern Africa. The paper addresses key management challenges in trying to upgrade rainfed agriculture, and presents a set of field experiences on system options for increased water productivity in smallholder farming. Implications for watershed management are discussed, and the links between water productivity for food, and securing of water flow to sustain ecosystem services are briefly analysed. Focus is on sub-Saharan Africa hosting the largest food deficit and water scarcity challenges.

The papers shows that there are no agro-hydrological limitations to doubling or even quadrupling on-farm staple food yields even in drought prone environments, by producing more "crop per drop" of rain. Field evidence is presented suggesting that meteorological dry spells are an important cause for low yield levels and it is hypothesised that this may constitute a core driver behind farmers risk aversion strategies, which contribute amongst others to the urgent soil fertility deficits due to insignificant investments in fertilisation. For many smallholder farmers in the semi-arid tropics it is simply not worth investing in fertilisation (and other external inputs) as long as the risk for crop failure remains a reality every 5th year with risk of yield reductions every 2nd year, due to periodic water scarcity during the growing season (i.e., not necessarily cumulative water scarcity).

Results are presented from field research on smallholder system innovations in the field of water harvesting and conservation tillage. Upgrading rainfed production systems through supplemental irrigation during short dry-spells, is shown to dramatically increase water productivity. Downstream implications of increased upstream withdrawals of water for upgrading of rainfed food production are discussed.

Finally it is argued that some of the most exiting opportunities for water productivity enhancements in rainfed agriculture are found in the realm of integrating components of irrigation management within the context of rainfed farming, e.g., supplemental or micro irrigation for dry spell mitigation. Combining such practices with management strategies that enhance soil infiltration, improve water holding capacity and plant water uptake potential, can have strong impact on agricultural water productivity. This suggests that it is probably time to abandon the largely obsolete distinction between irrigated and rainfed agriculture, and instead focus on integrated rainwater management.

INTRODUCTION

Water productivity in rainfed agriculture will have to increase dramatically over the next generation if food production is to keep pace with population growth. Almost the total population growth (95 %) and the bulk of present under-nutrition occur in tropical developing countries, of which a large proportion depends on rainfed agriculture for their livelihoods. In sub-Saharan Africa, e.g., over 60 % of the population depend on rain-based rural economies, generating in the range of 30 – 40 % of country GDP (World Bank, 1997). Rainfed agriculture in sub-Saharan Africa (SSA) is practised on approximately 95 % of the agricultural land (the remaining is under irrigated agriculture) and will remain the dominant source of food production during the foreseeable future (Parr et al, 1990). In general yields from rainfed agriculture are low, in many parts of the water-scarce tropical world oscillating around 1 t ha^{-1} (Rockström, 2001). There is ample evidence to suggest that the low productivity in rainfed agriculture is more due to sub-optimal performance related to management aspects than to low physical potential (Agarwal and Narain, 1997; Benites et al., 1998; Rockström and Falkenmark, 2000; SIWI, 2001). This means that in the developing countries experiencing the most rapid population growth, dependence on rainfed agriculture operating at a sub-optimal level is high. Furthermore, it has been estimated that there is limited new land to put under agriculture (McCalla, 1994; Young 1999), contrary to the last three decades in SSA when the bulk of increased food production originated from expansion of agricultural land. There is thus a growing pressure to increase agricultural productivity through raised yields per unit soil and unit water.

This paper presents the agro-hydrological rationale to focus on water productivity in rainfed agriculture, identifies key management challenges in the attempt to upgrade rainfed agriculture, and presents some field experiences on system options for increased water productivity in smallholder farming in drought prone environments. Implications for watershed management are discussed, and the links between water productivity for food, and securing of water flow to sustain ecosystem services are briefly analysed. The focus is on semi-arid and dry-sub-humid tropical agro-ecosystems where the importance of increase in water productivity is highest.

RAINWATER MANAGEMENT – THE RATIONALE

A broad approach to water productivity in land management that covers both irrigated and rainfed agriculture has implications on water resource management. Conventionally, focus on global, regional and national freshwater resources and withdrawals has been on the stable and accessible surface and sub-surface flow of water in rivers, lakes and groundwater, the so-called blue water branch in the hydrological cycle (UN, 1997, Cosgrove and Rijsberman, 2000). Blue water is withdrawn for direct blue (liquid) water uses in households, for municipalities, livestock and industry, but also as direct withdrawals for irrigated agriculture (of which the consumptive proportion eventually returns to the atmosphere as green vapour or evapotranspiration flow). Regionally there are signs of present or predictions of near-future physical scarcity of "blue" freshwater resources. IWMI (2000) estimated that some 30 % of the world population by 2025 may live in regions subject to physical water scarcity (read "blue" water scarcity). The fear of rapidly growing water scarcity problems especially in arid and semi-arid tropical regions of the world is based on analyses comparing blue water availability with actual blue water withdrawals and projections of future withdrawals based on general per capita water requirements. This approach has recently been criticized as it is based on an incompatible comparison of blue water availability with a general per capita freshwater demand (of which some 90 %, or 1,600 m^3 cap^{-1} d^{-1}, is required to cover daily food requirements) (Falkenmark and Rockström, 2000; Rockström, 2001). However, the conventional water resources assessments highlight the limited possibilities of expansion of direct blue water withdrawals. Globally, mankind withdraws some 4,000 Gm^3 yr^{-1} (Shiklomanov, 2000), which is projected to reach some 5,250 Gm^3 yr^{-1} in 2025 as a result of population growth and socio-economic development. This is a serious problem, in light of the global availability of blue freshwater flow estimated to 12,500 Gm^3 yr^{-1} (Postel, et al., 1996). Furthermore, the increased pressure on finite blue freshwater resources would suggest limitations in the opportunities of expanding the area under irrigation, and instead brings our attention to the green flow branch in the hydrological cycle. Of the global estimated average 110,000 Gm^3 yr^{-1} of precipitation over land areas, 38,000 Gm^3 yr^{-1} forms the blue runoff branch and the remaining 72,000 Gm^3 yr^{-1} forms the return flow of green water as evapotranspiration. Green water flow sustains rainfed agriculture, as well as all other water dependent ecosystems, such as forests, woodlands, grazing lands, grasslands, and wetlands.

Even though scientific attention has been given to partitioning of rainfall in rainfed agriculture, and to biophysical dynamics of green water flow at plant and production system level, relatively little attention has been paid to the opportunities at hand to improve agricultural water productivity within the large (relative to blue water flow) component of green water flow in the on-farm water balance and the hydrological cycle at catchment, basin and global level. In a first global estimate Rockström et al. (1999) estimated global withdrawals of green water to sustain rainfed agriculture at 4,500 Gm^3 yr^{-1}, compared to some 2,500 Gm^3 yr^{-1} estimated for irrigated agriculture (Shiklomanov, 2000).

Figure 1 shows the geographical distribution of green (rainfed) and blue (irrigated) water withdrawals to produce grain foods. Data on blue water withdrawals in irrigation are taken from IWMI (2000) as well as data on areas under rainfed agriculture and estimated grain yields in irrigated and rainfed farming systems. The green water withdrawals were calculated assuming a global water use efficiency in rainfed grain production of 3,000 m^3 t^{-1} grain (evapotranspiration flow). Countries where direct return flow of vapour from rain-fed agriculture accounts for over 80 %

of the water withdrawals for food production are shown in dark green, countries with a green water dependence of 60 - 80 % are shown in green. Countries depending to over 80 % on blue water withdrawals in conventional irrigation systems are shown in dark blue and countries in a blue water range of 60 - 80 % are shown in blue. Intermittent countries, with a blend of green and blue water dependence (a green water range of 40 - 60 %) are shown with horizontal lines. As seen from *Fig.* 1, the majority of countries (79 %) of the world depend predominantly on return flow of green water in rainfed agriculture to produce grain foods. Not surprisingly, the countries (predominantly in North Africa and the Middle East) that depend primarily on blue water withdrawals in irrigation for grain production, correspond with the countries in conventional water assessment predicted to be facing the most severe water scarcity problems.

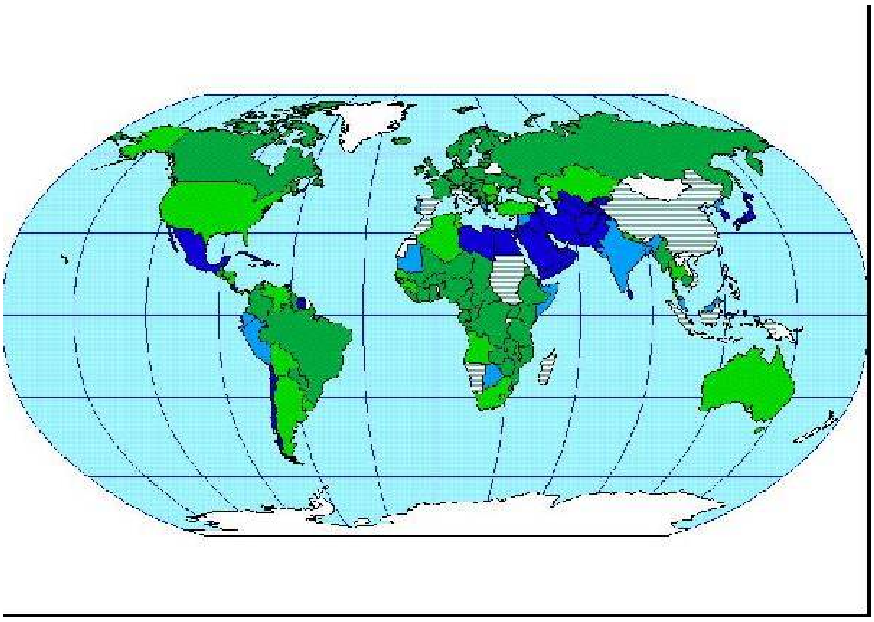


Figure 1. Predominant source of water flow - green or blue - to produce food at country level (grain). Dark green; Countries with >80 % green water dependence, i.e., > 80 % of water used to produce cereal foods originates from rain-fed agriculture: Green; countries where 60 - 80 % originates from green water: Dark Blue; countries with > 80 % blue water dependence, i.e., where > 80 % of water withdrawals for cereal food production originates from blue water: Blue; countries where 60 - 80 % originates from blue water. Countries with a mixed dependence, i.e., with 40 - 60 % green water dependence are shown with horizontal lines. Countries where some component of source data was lacking are marked in white.

Like all global water resources assessments, the country scale analysis gives little guidance on challenges and opportunities at the local scale. However, the blue-green analysis carried out here, indicates that there are opportunities to produce more food per drop of water if focus is tilted from the downstream blue runoff water resource to the upstream position where the rainfall enters the soil-plant system. A shift towards the source of water, i.e., towards rainwater management, forms a rationale entry point for integrated agricultural water management, that encompasses both green-rainfed withdrawals and blue-irrigation withdrawals.

Also, from the perspective of improved water productivity in rainfed agriculture, the shift towards upstream focus is crucial especially among resource poor smallholder farmers, as it puts emphasis on the possibility of water management that to a larger extent can benefit from unutilised energy from gravitational forces.

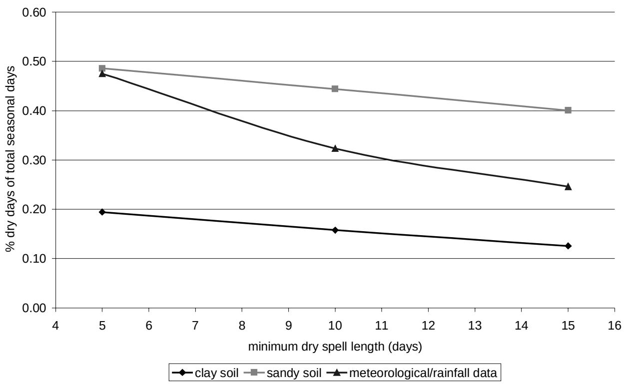
UPGRADING RAINFED AGRICULTURE – CHALLENGES AND OPPORTUNITIES

Hydroclimatic challenges

Water related problems in rainfed agriculture in water scarcity prone tropics are often related to high intensity and large spatial and temporal variability of rainfall, rather than low cumulative volumes of rainfall (Mahoo et al., 1999; Rockström et al., 1998; Sivakumar and Wallace, 1991). Rainfall is highly erratic, and rain often falls as convective storms, with high rainfall intensity and extreme spatial and temporal variability. Coefficients of variation range from 20 – 40 %, increasing with decreasing seasonal rainfall averages. The overall result of unpredictable spatial and temporal rainfall patterns is a very high risk for meteorological droughts and intra-seasonal dry spells. The annual (seasonal) variation of rainfall can typically range from a low of 1/3 of the long term average to a high of approximately double the average; meaning that a high rainfall year can have some 6 times higher rainfall than a dry year (Stewart, 1988). Generally, the hydro-climatic focus in semi-arid and dry sub-humid tropics is on occurrence of meteorological droughts. Statistically for semi-arid regions total crop failures caused by meteorological droughts occur in the order of once every 10 years (Stewart, 1988).

Research from several semi-arid tropical regions show that the occurrence of dry spells, short periods of 2 – 4 weeks with no rainfall, far exceeds the occurrence of droughts. Stewart, based on research in East Africa, indicated that severe crop reductions caused by a dry spell occur 1-2 out of 5 years, and Sivakumar (1992), showed that the frequent occurrence of seasonal dry spells in the range of 10-15 days were independent of long-term seasonal averages ranging from 200 to 1200 mm in West Africa .

Barron et al. (*in prep*) studying dry spell occurrence in semi-arid locations in Kenya and Tanzania, showed a minimum probability (based on statistical rainfall analysis) of 0.2 – 0.3 of a dry spell exceeding 10 days at any time of the growing season of a crop, and a probability of 0.7 for a > 10 day dry spell occurring during the stress sensitive flowering stage (maize). The analysis also highlighted the importance of re-visiting the on-farm water cycle when assessing drought and dry-spell risk, i.e., the occurrence of agricultural droughts/dry spells, which are conditioned by the actual crop access to soil moisture, i.e., by management and biophysical conditions such as soil, vegetation, slope etc.. This is in contrast to the common approach of basing the analysis on rainfall data only, which gives an indication of the occurrence of meteorological droughts and dry spells. Figure 2 shows the occurrence of meteorological and agricultural dry spells for a typical sem-arid setting in East Africa based on smallholder cultivation on maize on sandy and clay soil (using rainfall data during 1977-1998). Occurrence of dry spells is denoted as the average number of days (as percent of total days during a rainy season) during a rainy season that have been subject to at least 5, 10 and 15 consecutive dry days. Long rains are shown in *Fig.* 2a and short rains in *Fig.* 2b. The three lines show dry spell occurrence based on rainfall data only (intermediate line) and occurrence based on water balance modelling on sandy soil (upper line) and clay soil (lower line). A dry day in the rainfall analysis is defined only as a day with no rainfall, while a dry day in the water balance analysis is defined as a day when plant water availability in the root zone < half the daily crop water requirement. Dry spell occurrence is persistently higher on a sandy soil than suggested by rainfall analysis alone, with 30 – 40 % of the days during a rainy season are preceeded by at least 15 consecutive dry days. A clay soil, on the other hand, has the capacity to buffer the effect of no-rainfall days, thanks to the relatively (to sand) higher water holding capacity in the soil. Nevertheless, 15 % of the days during a rainy season (or 15 days for a 100 day maize variety) have a history of at least 15 consecutive dry days.



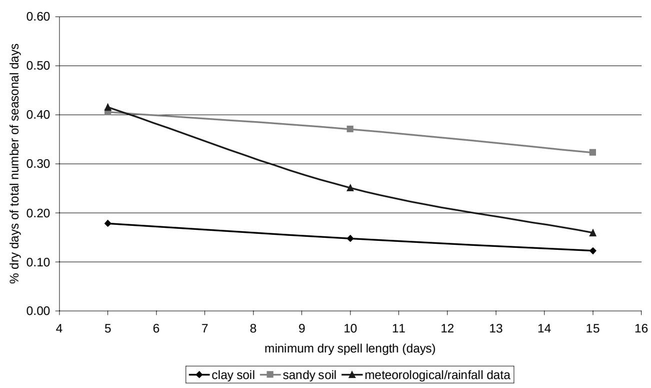


Figure 2a and b. Occurrence of number of days as percent of total number of days when dry spell length exceeded 5, 10 and 15 days for rainfall data (meteorological), maize crop on clay soil and sandy soil during 1977-1998 long rains (left) and short rains (right) for a typical East African farming conditions.

The above indicates that mitigating dry-spells is a key to improved water productivity in rainfed agriculture in semi-arid and dry sub-humid tropical environments. There are three major avenues to achieve this:

- Maximize plant water availability (maximize infiltration of rainfall, minimize unproductive water losses (evaporation), increase soil water holding capacity, and maximize root depth).
- Maximize plant water uptake capacity (timeliness of operations, crop management, soil fertility management).
- Bridge crop water deficits during dry-spells through supplemental irrigation.

Hydroclimatic opportunities

The on-farm water balance is an entry point to analyse the opportunities available to improve water productivity. Figure 3 gives a synthesised overview of the partitioning of rainfall in semi-arid rainfed agriculture, based on research experiences in sub-Saharan Africa.

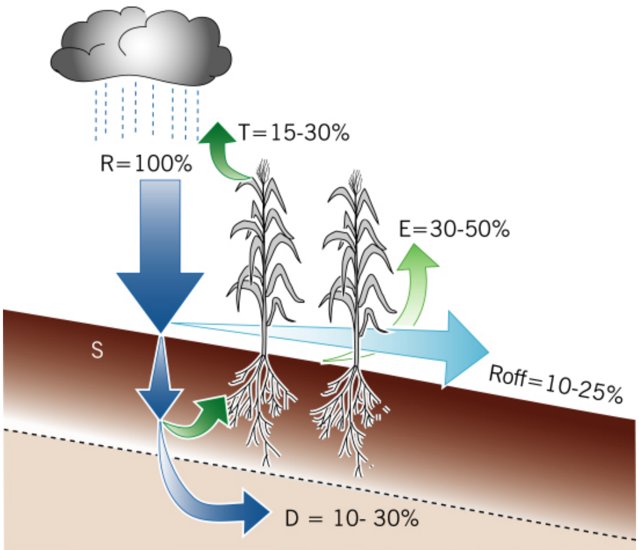


Figure 3. General overview of rainfall partitioning in farming systems in the semi-arid tropics of sub-Saharan Africa.

Between 70 – 85 % of rainfall can be considered "lost" from the cropping system as non-productive green water flow (as soil evaporation) and as blue water flow (deep percolation and surface runoff). This data originates primarily from research stations operating at higher crop yield levels than most small-holder farmers. For the on-farm situation, under degraded and low-input conditions, the productive proportion of the water balance can be less than 10 %. The conclusion is that there is a high seasonal risk of soil water scarcity in crop production, irrespective of spatial and temporal rainfall variability.

From a water productivity perspective the question is how far crop yields can be increased in rainfed agriculture. Rockström and Falkenmark (2000) developed an analytical tool for assessing the options available to improve crop yields in semi-arid tropics from a hydrological perspective. They showed that there is a large scope for improving yield levels within the available water balance in rainfed farming systems. It seems that there are no agro-hydrological limitations to enable even a large and stable yield increase from, e.g., 0.5 t ha^{-1} to 2 t ha^{-1} (i.e., a quadrupling of yields) in semi-arid environments. The challenge is to maximize infiltration, mitigate dry-spells and to improve primarily soil fertility management in order to increase the ratio of productive to non-productive green water flow.

WATER PRODUCTIVITY – SYSTEM OPPORTUNITIES

Supplemental irrigation

Bridging dry spells through supplemental irrigation of rainfed crops can be an interesting option to increase water productivity at production system level (Oweis et al., 1999; SIWI, 2001). Supplemental irrigation in smallholder farming systems can be achieved with water harvesting systems that collect local surface runoff (sheet, rill and gully flow) in small storage structures (100 – 1000 m^3). Water harvesting, broadly defined as the concentration of surface runoff for productive purposes, has ancient roots and still forms an integral part of many farming systems worldwide (Evanari et al., 1971; Agarwal and Narain, 1997). However, in-situ systems aiming at water conservation (i.e., maximising soil infiltration and water holding capacity) dominate, while storage systems for supplemental irrigation are less common, especially in sub-Saharan Africa (SIWI, 2001).

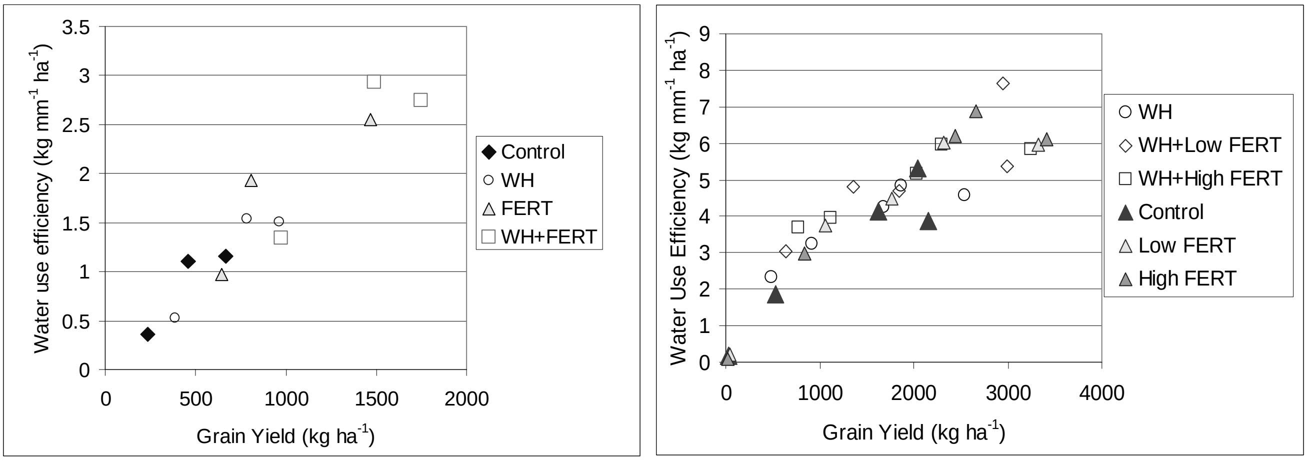


Figure 4. Water use efficiency (kg grain per unit rainfall + supplemental irrigation) for sorghum in Burkina Faso (4a, left) and for maize in Kenya (4b, right). Control = traditional farmers' practice with no fertiliser application, WH = supplemental irrigation using water harvesting, FERT = fertiliser application (30 kg ha^{-1} N in Burkina Faso, and two levels in Kenya with Low-30 kg N ha^{-1} and High-80 kg N ha^{-1}).

On-farm research in semi-arid locations in Kenya (Machakos district) and Burkina Faso (Ouagouya) during 1998-2000 indicates a significant scope of improving water productivity in rainfed farming through supplemental irrigation, especially if combined with soil fertility management (Barron et al., 2000; Fox and Rockstrom, 1999). Surface runoff from small catchments (1 – 2 ha) was harvested and stored in manually dug farm ponds (100 – 250 m^3 storage capacity). Simple gravity-fed furrow irrigation was used. During the three and five experimental rainy seasons in Burkina Faso (mono-modal rain pattern) and Kenya (bi-modal rain pattern), respectively, supplemental irrigation amounted on average to 70 mm per growing season with a range of 20 – 220 mm. Seasonal rainfall ranged from 196 – 557 mm in Kenya and 418 – 667 mm in Burkina Faso. In Kenya one rainy season was classified as a meteorological drought (short rains of 1998/99) resulting in complete crop failure, while one season at each site (long rains 2000 in Kenya and the rainy season 2000 in Burkina Faso) resulted in complete crop failure for most neighbouring farmers, while the water harvesting system enabled the harvest of an above average yield (> 1 t ha^{-1}). Grain yields and rain use efficiencies (kg dry matter grain per mm rainfall) for the studied water harvesting system are shown for sorghum in Burkina Faso (Fig. 4a) and for maize in Kenya (Fig. 4b). Each point represents an average combination from five replicates of water harvesting/fertiliser application for a certain rainy season. In Burkina Faso, on shallow soil with low water holding capacity, supplemental irrigation alone improved water use efficiency (rainfall + irrigation) with 37 % on average (from 0.9 to 1.2 kg mm^{-1} ha^{-1}) compared to the control (traditional rainfed practice with manure but no fertiliser). The corresponding figure for the Kenyan case, on deep soil with high water holding capacity, was 38 % (from 2.2 to 3.1 kg mm^{-1} ha^{-1}). The highest improvement in yield and *WUE* was achieved by combining supplemental irrigation and fertiliser application. Interestingly, for both locations, fertiliser application alone (in Kenya with low application of 30 kg N ha^{-1} and high application of 80 kg N ha^{-1}) resulted in higher average yield and *WUE* than water harvesting alone, during years with gentle dry spells (for seasons with severe dry spells, e.g., long rains 2000 in Kenya, non-irrigated crop resulted in complete crop failure). Nevertheless, it indicates that full benefits of water harvesting for supplemental irrigation can only be met by simultaneously addressing soil fertility management.

The relative contribution to system productivity of supplemental irrigation is assessed by calculating the incremental water use efficiency of using (kg additional grain produced per mm of supplemental irrigation). As seen in Table 1, the incremental *WUE* is substantially higher (ranging from 2.5 – 7.6 kg ha^{-1} mm^{-1} compared to overall *WUE* of 0.9 – 1.2 kg ha^{-1} mm^{-1}) than the seasonal *WUE*. The situation is more complex on soil with capacity to cope with dry spells as illustrated by the Kenyan case (Table 2). Incremental water productivity improvements are only achieved during rainy seasons with severe dry spells, while rainy seasons with adequate amount and good distribution (short rains 99/00 and 00/01) the incremental value can be negative.

Table 1. Incremental water use efficiency of supplemental irrigation (Burkina Faso).

Fertiliser application	1998 [kg ha^{-1} mm^{-1}]	1999 [kg ha^{-1} mm^{-1}]	2000 [kg ha^{-1} mm^{-1}]
Non-fertilised	4.92	2.50	3.63
Fertilised	4.62	5.42	7.58

Table 2. Incremental water use efficiency of supplemental irrigation (Kenya).

Fertiliser application	SR 1998/99 [kg ha^{-1} mm^{-1}]	LR 1999 [kg ha^{-1} mm^{-1}]	SR 1999/00 [kg ha^{-1} mm^{-1}]	SR 2000/01 [kg ha^{-1} mm^{-1}]
0F	6.03	6.28	-9.31	19.93
30F	3.46	4.84	32.68	-17.18
80F	2.85	4.39	-19.07	-8.06

Water harvesting for micro-irrigation

For resource poor small-holder farmers in water scarce areas even small volumes of stored water for supplemental irrigation can significantly improve household economy. In the Gansu Province in China small 10 – 60 m^3 (on average 30 m^3) sub-surface storage tanks are promoted at large scale. These tanks collect surface runoff from small, often treated catchments (e.g., with asphalt or concrete). Research using these sub-surface tanks for supplemental irrigation of wheat in several counties in Gansu Province (Li et al., 2000) indicate a 20 % increase in water use efficiency (rain amounting to 420 mm + supplemental irrigation ranging from 35 – 105 mm). Water use efficiency increased on average from 8.7 kg mm^{-1} ha^{-1} for rainfed wheat to 10.3 kg mm^{-1} ha^{-1} for wheat receiving supplemental irrigation. Incremental water use efficiency ranged from 17 – 30 kg mm^{-1} ha^{-1}, indicating the large relative added value of supplemental irrigation. Similar results were observed on maize, with yield increases of 20 – 88 %, and incremental water use efficiencies ranging from 15 – 62 kg mm^{-1} of supplemental irrigation (Li et al., 2000).

The irrigable land from these sub-surface tanks is limited to 400 – 800 m^2. In many farming communities they may be mostly interesting for cultivation of high value cash crops. A survey in Kenya among small-holder farmers, indicate that farmers would rarely consider supplemental irrigation of food crop, and would rather use stored water for irrigating cash crops (Svensson and Jurdell, 1998). Inspired by the Chinese sub-surface tanks, similar systems are at present being developed and promoted in Kenya and Ethiopia (Shone pers. comm.). In Kenya (Machakos district) these tanks are used to irrigate kitchen gardens, and enable farmers to diversify sources of income from the land. The micro-irrigation schemes are promoted together with commercially available low-pressure drip irrigation systems. Cheap drip kits (e.g., the Chapin bucket kit) save water and labour, and are increasingly adopted among farmers in, e.g., Kenya. Combining water harvesting with drip irrigation can result in very significant water productivity improvements (Ngigi et al., 2000).

Conservation tillage

There is ample research indicating that the conventional farming system in the tropics, based on soil inversion using plough and hoe, contributes to soil erosion and soil desiccation. Plough pans impede soil infiltration and root penetration, and frequent soil inversion results in oxidation of organic matter and soil erosion by wind and rain (Benites et al., 1999). Conservation tillage (*CT*) covers a spectrum of non-inversion practices from zero-tillage to reduced tillage, which aim at maximizing soil infiltration and soil productivity, and minimizing water losses while conserving energy and labour. Even though conservation tillage is not a new phenomenon, the relatively recent successes, e.g. in Brazil (Derpsch, 1998), has inspired research and development efforts in sub-Saharan Africa and Asia. Examples of successful *CT* systems, where crop yields have been significantly increased, soil erosion reduced and conservation of water improved, can be found in several countries in sub-Saharan Africa, e.g., Ghana, Nigeria, Zimbabwe, Tanzania, South Africa and Zambia (Elwell, 1993; Oldreive, 1993). However, these successes are mostly confined to commercial farmers.

Conservation tillage has several attractive water productivity attributes. Traditionally, conservation in agriculture has focused on soil conservation (even though labeled soil and water conservation), with the aim of reducing soil erosion. Even success stories like the *Fanya juu* terracing in Machakos district, Kenya (Tiffen et al., 1994) show little or no evidence of actual improvements of water productivity in agriculture. The recently raised question of "what to do between the terraces" in order to increase crop yields and how to increase "crop per drop of rain", has shifted focus towards conservation tillage. Also, conservation tillage enables improved timing of operations, which is crucial in semi-arid rainfed farming, and has (compared, e.g., to storage water harvesting) the attraction of being applicable on most farm land.

There are several examples of water productivity improvements using *CT* in rainfed farming. Zero tillage research using planting drills on wheat in Pakistan show water savings of 15 – 20 % (on average an estimated 100 mm ha^{-1}) through reduced evaporation, runoff and deep percolation, while increasing yields and saving on fuel (Hobbs et al., 2000).

Promotion of animal and tractor drawn conservation tillage using rippers and sub-soilers among small-holder farmers in semi-arid Babati district, Tanzania, has over the last decade resulted in significant water productivity increases. As seen from *Fig.* 5 rain use efficiency was estimated at approximately 1.5 kg mm^{-1} ha^{-1} in the mid-80s under conventional disc-plough agriculture, compared to a progressively increasing trend from 2 to 4 kg mm^{-1} ha^{-1}, during the 1990s after introduction of mechanized sub-soiling (Rockström and Jonsson, 1999).

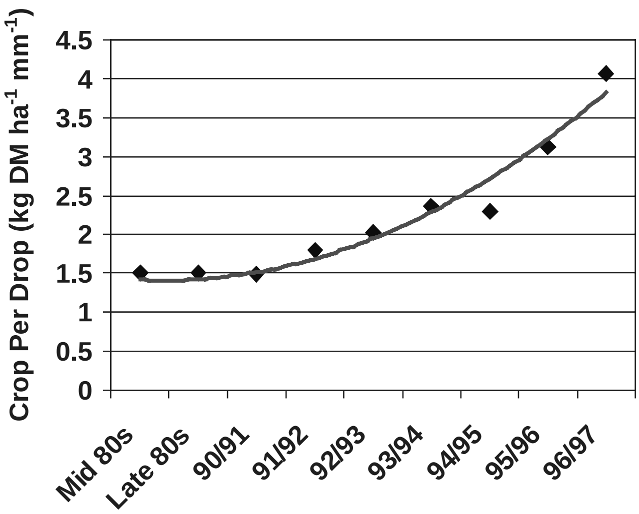


Figure 5. Development of rain use efficiency (kg DM grain mm^{-1} ha^{-1}) of maize in Babati district, Tanzania, before introduction of conservation tillage (Mid 80s to 90/91) compared to after introduction of conservation tillage (91/92 onwards).

Table 3. Rain use efficiency (kg mm^{-1} ha^{-1}) showing variation (SD) and statistical T-Test analyses (comparing conservation tillage practices with conventional ploughing with or without fertilizer application). Ripper = Magoye ripper, Ripper + CC = Magoye ripper + cover crop (*Dolicos Lab-lab*), Ripper – FERT = Magoye ripper without fertilizer application, C + FERT = conventional moulboard plough with fertilizer application, and C - FERT = ploughing without fertilizer application.

			Comparative analysis			
			Control no Fertiliser		Control with Fertiliser	
Treatment	RUE [kg mm^{-1} ha^{-1}]	SD	Sign.	Multiplyer	Sign.	Multiplyer
Ripper	10.1	4.9	***	2.8	*	1.4
Ripper + CC	10.6	5.8	***	2.9	**	1.5
Ripper - FERT	8.4	3.7	***	2.4		1.2
Pitting	8.2	4.1	***	2.3	*	1.2
C+FERT	7.0	4.4	***	2.0		
C	3.6	2.2				

On-farm trials on animal-drawn and manually based conservation tillage systems (Magoye ripper and Palabana sub-Soiler from Zambia developed by IMAG-DLO) in Arusha and Arumeru districts, Tanzania, show similar improvements in water productivity. Rain use efficiencies increased when shifting from a mouldboard plough based system (C = control) to various conservation tillage practices (Table 3). The data originates from two years (long rains 1999 and 2000) with 6 – 8 farmers and two replicates per farm. The improved water use efficiencies are explained primarily by improved timing of planting, root penetration and soil infiltration.

Watershed management

Upgrading rainfed agriculture in semi-arid tropical environments will require planning of land management at the watershed scale, rather than the conventional focus on farm or field level. A shift is needed from the "conservation" approach where surface runoff entering a farm is seen as a threat to be disposed of (e.g., with graded cut-off drains), to a "productivity" approach where surface runoff generated in one part of a watershed is collected and used as a resource both for agricultural and domestic purposes. Such planning is complex among small-holder farmers as even a small runoff collecting system will involve multiple land owners. At present there is little or no attention given to ownership of locally produced surface runoff, but one may expect this to become an issue of importance if runoff to a larger extent is successfully managed for local production purposes. As shown from several hydrological studies at watershed and basin scale, upstream shifts in water flow partitioning may result in complex and unexpected downstream effects, both negative and positive, in terms of water quantity and quality (Vertessey et al., 1996). In general though, increasing the residence time of runoff flow in a watershed, e.g., through practices like water harvesting and conservation tillage, may have positive environmental as well as hydrological implications downstream.

Furthermore, there is evidence supporting the notion that overall gains and synergies can be made by maximising the efficient use of every raindrop, where it falls (and not wait until it has, after a generally erosive journey, formed a perennial river downstream that may be tapped). This rationale is in line with Evanari (1971), who showed that a larger effective volume of water in a catchment can be generated for productive agricultural use, through numerous small water harvesting structures scattered in a catchment (collecting local surface runoff) compared to one large storage structure located downstream. Similarly, using the rationale of Seckler et al. (1998) on the erroneous view that all water applied in irrigation is consumptive (large proportion of the flow can be reused elsewhere), a unit of efficiently used local rainwater, does not necessarily mean a unit lost for downstream use. For example, many water harvesting systems have as both direct and indirect objective of shifting flow partitioning, e.g., from surface to sub-surface runoff, rather than increasing consumptive use (Scott et al., forthcoming).

However, the fact remains that the hydrological implications at watershed and river basin scale of upscaling system innovations such as water harvesting are still unknown and require further research.

SYSTEM IMPLICATIONS – BALANCING WATER FOR FOOD AND NATURE

Increasing withdrawals of water in rainfed and irrigated agriculture may have negative implications on water availability to sustain direct human withdrawals and indirect withdrawals to sustain ecosystem services. As shown by Rockström et al. (1999) almost the totality of global green water flow (88 %) is already at present used to sustain biomass growth in the World's biomes. While agriculture (rainfed and irrigated) annually accounts for an estimated 7,000 $Gm^3\ yr^{-1}$, forests and woodlands require an estimated average green water flow of 40,000 $Gm^3\ yr^{-1}$, grasslands an estimated 15,100 $Gm^3\ yr^{-1}$ and wetlands an estimated 1,100 $Gm^3\ yr^{-1}$. This paper suggests that a promising avenue of upgrading rainfed agriculture is through water harvesting that enables mitigating of dry spells. Such measures involved adding a blue water component, through storage of surface or sub-surface runoff, to the rainfed system, i.e., developing rainfed farming into a more blended system with an irrigation component. Carried out at large scale (e.g., at basin level) may have implications on downstream blue water availability. However, it is not certain that an increase in return flow of evapotranspiration in rainfed agriculture upstream per automatic results in reduced water availability downstream. Surface runoff generated at the farm level, may be lost during its journey through the catchment, as evaporation or as blue water of limited use in saline rivers, before reaching a stable surface or sub-surface freshwater resource. It is also important to note the large uncertainty involved in estimating green water flow in agriculture, as not only rainfall but also green water flow, present large spatial and temporal variability. On average grain crop water use efficiencies (WUE_{ET}) range between 3.5 – 10 kg mm^{-1} ha^{-1} (1,000 – 3,000 m^{3} t^{-1}) for tropical grains. However, as WUE_{ET} is affected by biophysical factors as well as management, the actual experienced range is much wider, with WUE_{ET} values as low as 1.5 kg mm^{-1} ha^{-1} (6,000 – 7,000 m^{3} t^{-1}) for degraded and poorly managed systems not being uncommon in rainfed drylands (Rockström et al., 1998).

CONCLUSIONS AND DISCUSSION

There is no doubt that the immense challenge of doubling food production over the next 25 years in order to keep pace with population growth, requires increased attention to water productivity and rainwater management, simply making the best use of the local water balance. As shown in this paper, even in water scarcity prone tropical agro-ecosystems, there is seemingly no hydrological limitation to doubling or in many instances even quadrupling staple food crop yields in rainfed small-holder agriculture. Furthermore, evidence suggests that there are several appropriate technologies and methodologies at hand to enable a development towards improved soil and water productivity.

Interestingly, even when focusing on water productivity in semi-arid rainfed farming systems (where water is a major limiting factor for crop growth), other factors than water are shown to be at least as (if not even more) critical limiting factors for productivity improvements. The experiences on water harvesting for supplemental irrigation in Burkina Faso and Kenya, clearly showed that soil fertility management plays an as important role as water management (in the Kenyan case fertiliser application alone on average resulted in higher water productivity and yields than supplemental irrigation alone). Similarly, for in-situ water harvesting using conservation tillage in Tanzania, addressing water conservation only (through ripping and sub-soiling) resulted in similar yields and water productivity as addressing soil fertility alone (in conventionally ploughed systems). The only win-win opportunity in these examples, arise when soil fertility and water are managed simultaneously, as shown in the water harvesting experiments in Burkina Faso, where isolated management of water or soil fertility resulted 1.5 - 2 times higher yield compared to the traditional practice, while integrated soil nutrient and water management resulted in a factor 3 times higher yield.

However, these biophysical facts play only a limited role in decision making at farm level. Farmers' investment decisions are strongly influenced by their risk perceptions. Risk of reduced or no return on invested capital in rainfed semi-arid farming is directly related to the unreliable rainfall distribution. Therefore, as long as farmers "live at the mercy of rainfall" one should not be surprised at the extremely low level of investments in fertilisers (less than 20 kg ha^{-1} yr^{-1} in sub-Saharan Africa), improved crop varieties, and pest management. Managing water, especially by introducing the farmers to a tool to bridge recurrent dry spells (e.g. through small-scale water harvesting), may be the most sustainable entry point for farming systems improvement in general (subsidized credit schemes to enable fertiliser purchase will always attract farmer investments on the short term but are generally not in themselves sustainable on the long run). This form of upgrading of rainfed farming may be the incentive required to stimulate capital and time investment in small-holder rainfed farming. All evidence suggests that if only crop water access is secured investments in soil fertility, crop, and timing of operations, will pay-off in terms of substantially increased soil and water productivity.

This paper has not addressed the important aspects of social and economic viability of, e.g. water harvesting structures for supplemental irrigation among resource-poor farmers. Tentative assessments of manually dug farm ponds and sub-surface tanks indicate that the economic viability to a large extent depends on the opportunity cost of labour. If labour is valued low (which often can be justified during, e.g., dry seasons in remote rural areas) and account is taken for the dramatic difference the systems can play during years of severe dry spells (basically the difference between total crop failure and having a crop), the investment can be rapidly recovered and afforded. However, this is an area in need of more detailed studies, with account taken to local environmental, institutional and socio-economic conditions.

As shown in this paper the most interesting opportunities of upgrading small-holder rainfed agriculture may be found in a realm of sectoral and economic system integration and diversification. Reducing risk for crop failures by adding a component of supplemental irrigation, implies the development of blended farming systems including components of both rainfed and irrigated agriculture. The time may be ripe to abandon the sectoral distinction between irrigated and rainfed agriculture. The implications of such a reform would be substantial. Professionally there is still a divide between irrigation engineers dealing with irrigation management and agronomists dealing with rainfed agriculture. Irrigation and rainfed agriculture generally fall under different ministries (irrigation under “blue” water resources ministries and rainfed agriculture under “green” ministries of agriculture, natural resources or environment). Integrating the two may result in interesting management and technological advances in the grey zone between the purely blue and purely “green” food producing sectors.

Blended upgrading also opens the door for farming systems diversification. A small-holder farmer’s investment in supplemental irrigation will be an entrepreneurial business step, which most likely will result in a broadened basket of crops produced at farm level. This will reduce farmers’ vulnerability to external climatic factors, but will also put increased pressure on the need for functioning markets and infrastructure. Diversification into a relatively lower proportion of staple food crops in favour of cash crops can have interesting virtual water implications. A shift from a staple food crop to a cash crop with similar water use efficiencies but different market value, can give rise to virtual water gains. If the same amount of water can be used to generate a higher market price then the economic gain can be used to buy food grain, i.e., virtual water, from regions with a relatively higher (hydrological) comparative advantage to produce staple foods. In summary, even though there is a wide range of complex biophysical and socio-economic factors affecting water productivity in rainfed farming systems in semi-arid tropics, starting by reducing risks of crop failure caused to crop water stress may be the vital key to trigger a much needed positive spiral of agricultural development in the small-holder sector.

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The use of garden boreholes in Cape Town, South Africa: Lessons learnt from Perth, Western Australia

I. C. SAAYMAN[1] and S. ADAMS[2]

[1]Water Programme, CSIR, PO Box 320, Stellenbosch, 7599
[2]Groundwater Group, Earth Science Department, University of the Western Cape, Private Bag X17, Bellville, 7535

[1] isaayman@csir.co.za

ABSTRACT

The similarities in climate and geology offer water resource managers in Cape Town and Perth an opportunity to learn from each other's experiences. While Cape Town relies mostly on surface water for supply, Perth uses 50 % groundwater for its domestic and industrial use. It is proposed that certain aspects of Perth's water supply infrastructure could successfully be transposed for the exploitation of Cape Towns' groundwater resources. In Perth private boreholes is used to tap a shallow phreatic aquifer for garden irrigation. The Government of Western Australia encourages this practice. Cape Town has an opportunity to use water from the Cape Flats Aquifer in a similar manner. In this paper the use of the Cape Flats Aquifer for private garden irrigation is evaluated. By encouraging private landowners to develop private wells, large savings could be made in the amount of treated bulk water supply required by Cape Town. The Cape Flats Aquifer has the potential to meet a large part of the city's garden irrigation requirements. Though the impact of pollution on water quality remains uncertain and a concern, the general quality of water in the aquifer is adequate for irrigation requirements. If the use of private garden boreholes is to be successful, education of the public will be vital. It is envisaged that the City of Cape Town and the Department of Water Affairs and Forestry in partnership with private, education and research institutions take the lead in such education and the development of appropriate legislation and guidelines.

Keywords: *Cape Flats Aquifer; garden boreholes; groundwater management*

INTRODUCTION

Groundwater has played an important role in the economic and social development of both South Africa and Australia. The history of water resources development in the two countries has resulted in disparate emphases on the present day use of groundwater. While water supply in Cape Town has largely focused on the use of surface water resources, Perth largely uses groundwater for domestic water supply. As a consequence of its focus on using groundwater, Perth has seen a proliferation of domestic boreholes used for garden irrigation. This strategy has resulted in savings in the city's treated water use. An opportunity exists for Cape Town to implement a similar strategy as a means of more effective water resources management.

This paper evaluates the feasibility of using privately owned boreholes and wellpoints in the Cape Town Metropolitan Area for garden irrigation. In most of the suburbs in the City of Cape Town water applied to household and public gardens, sports fields and recreational areas constitutes a large part of the city's annual treated water use. In Perth the use of garden boreholes as an alternative to potable water for garden irrigation is successful. Cape Town is increasingly being faced with the water shortages and a rapidly growing population. New and innovative strategies are thus required to address the city's water resource challenges. The similarity in climate and geology that Cape Town shares with Perth offers it a unique learning opportunity. One such lesson may be that the use of garden boreholes can be an effective measure in sustainable water resources management.

Geographical Setting

Cape Town and Perth are located on a similar latitude and share a common climatic regime (Figure 1). Located at the southern tip of Africa, Cape Town finds itself surrounded by ocean and prominent mountain ranges. Reaching heights of up to 2000 meters above sea level these mountains provide a natural barrier to rain bearing frontal systems approaching the African continent from the south Atlantic. As a result, high rainfall is recorded on Table Mountain and in the high mountains found to the north and northeast of Cape Town. Values recorded vary between about 1800 mm/annum on Table Mountain to about 3800 mm/annum in Jonkershoek and near Franshoek (Le Maitre, pers. comm., 2001, Wicht, et al., 1969).

The topographic low, located between Table Mountain and the Drakenstein and Hottentotsholland mountains, is known as the Cape Flats. Average rainfall over the area of the Cape Flats is much less than in the surrounding mountains, and averages about 600 mm per annum, with most rainfall occurring during winter (see Figure 2). Large parts of the Cape Flats are covered by urban development. Today most of the city's population lives within the area of the Cape Flats. Based on 1996 census figures (Statistics South Africa, 1996) the 2001 population of the larger Cape Town Metropolitan area was estimated at just over 3 million (Dorrington, 2000).

The city of Perth is located on the southwest corner of Australia. With a population of 1.4 million it is by far the largest urban centre in Western Australia. With a relative abundance of land, most of the population live in detached houses with large gardens. A Mediterranean climate characterized by wet winters and dry summers means that most households require garden irrigation for large parts of the year. The city is located on the highly permeable Swan Coastal Plain, of quaternary sand and limestone, which is separated from the crystalline rocks of the Darling Range by the Darling scarp. Average annual rainfall for Perth ranges between 700 and 1300 mm per year (see Figure 2), while average annual evaporation is about 1800 mm per year (Sililo and Appleyard, in print).

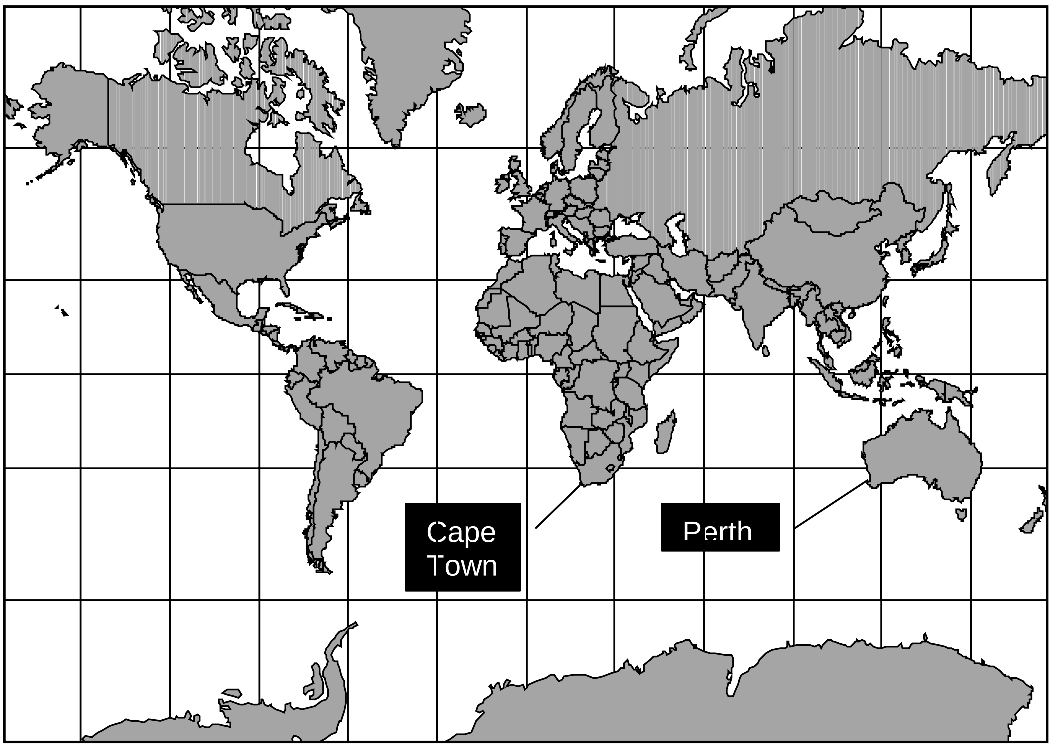

Figure 1: Locations of Cape Town and Perth

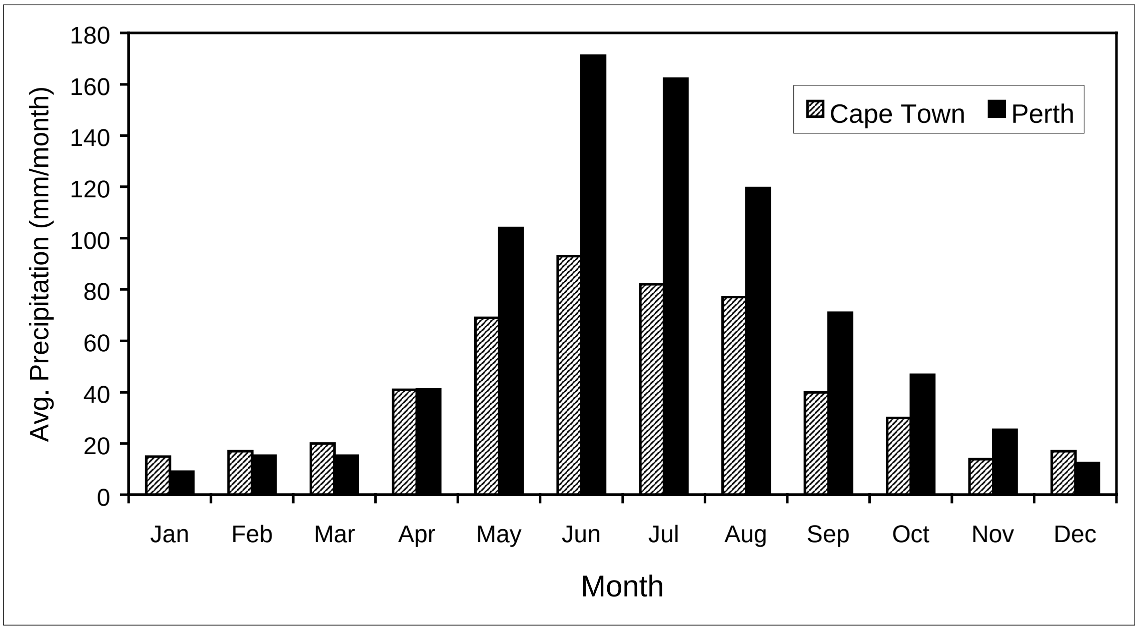

Figure 2: Average monthly precipitation in Cape Town and Perth. (Source: South African Weather Service and Australian Bureau of Meteorology)

HYDROGEOLOGY

Cape Town shares with Perth the occurrence of an unconsolidated shallow aquifer beneath the city. In Cape Town it is known as the Cape Flats aquifer, while in Perth similar deposits are found within the Swan Coastal Plain. The unconsolidated sediments of the Cape Flats Aquifer were formed by alluvial and eolian deposition. The average thickness of the Cape Flats Aquifer deposits is about 30m. The water table is shallow, ranging from a few centimetres below ground surface in winter months to about 4m in summer. A secondary hard rock aquifer is found below the primary unconsolidated aquifers consisting of Malmesbury shales and intrusive granites.

Conversely, the Swan Coastal Plain consists of highly permeable sand and sand/limestone dunes (Appleyard, et al., 1999). These superficial sediments extend to a depth of about 100m with the average depth being around 50m. This surficial aquifer is underlain by an extensive sedimentary basin containing aquifer units that to a depth of up to 3000 meters.

CURRENT STATUS OF WATER SUPPLY

Cape Town

Present water resources management in Cape Town has been largely shaped by the abundance of surface water resources in the form of perennial streams that have their origin in the mountain ranges. With the establishment of a European settlement at the Cape by Dutch mariners in the 17th century, their choice of settlement was based on the availability of surface water resources.

Most of the water in the Cape Town Metropolitan area is derived from surface water sources. Some municipal departments and private institutions do use groundwater and reclaimed sewage water for irrigation. However, the use of reclaimed water is often more costly than groundwater, as it usually requires treatment to an acceptable quality before use, and require additional infrastructure (such as separate pipelines and pumping stations).

Perth

Perth is a growing city that experiences a continued increase in water demand. Presently the city relies on surface reservoirs and groundwater for domestic supply. Annual domestic consumption is about 250 million m^3. Of this 50 % is derived from groundwater. However, it is estimated that an additional 184 million m^3 is abstracted from 150 000 private boreholes for garden irrigation (Water and Rivers Commission, pers. comm., 2001, Appleyard, et al., 1999). It is estimated that 1 house in every 4 has a private borehole that is used for garden irrigation (Appleyard, et al., 1999). Many of these boreholes were drilled during the water restrictions of the late 1970s, and reflect the value that is attached to private gardens. Through the use of private boreholes a great weight has been taken off the scheme supply. In this way the city saves in the amount of treated supply needed, thus extending the life of water supply schemes.

The use of private boreholes has not been without problem. Of particular concern is the environmental impact of over-abstraction. One reason for this is that individuals with private boreholes tend to use more water than those using mains water for gardens. On an average 1000 square meter house block water use for garden irrigation from mains supply ranges between 300-600 kL/year, compared to about 1000 kl/year average borehole abstraction Water and Rivers Commission, pers. comm., 2001).

The private boreholes are primarily used for garden irrigation and abstract water mainly from the shallow unconfined aquifer. The City's groundwater supply is abstracted from both the unconfined aquifer and from deeper semi-confined aquifers. The boreholes drilled into the deep semi-confined aquifers often exceed depths of 800m. The quality of water in both the unconfined and the deeper aquifers is generally good, with total dissolved solids content below 250 mg/L (Appleyard, et al., 1999).

Garden boreholes play an important role in the city's water supply infrastructure. Through the use of private boreholes the city's water supply burden is lightened, saving other water resources and money. Despite the free access that private citizens have to the Perth coastal plain aquifers, concerns over environmental impacts and a period of exceptionally dry summers has resulted in Perth water authorities imposing restrictions on water use, irrespective of its source. Such restrictions include appropriate garden watering times, with a ban on daytime sprinkler use.

GARDEN BOREHOLES AS AN ALTERNATIVE

The experience of Perth in the use of private boreholes for garden irrigation has been a good one. With so many similarities between Perth and Cape Town it begs the question on whether a similar initiative in Cape Town would be of benefit to the city.

The use of private boreholes for garden irrigation has in Perth resulted in a reduction in the amount treated domestic water used. The increased use of private garden boreholes in Cape Town would similarly result in less treated domestic water being used in garden irrigation. It is estimated that about 30% of the treated domestic supply to Cape Town water users is applied to garden irrigation (Parsons, 2000). With annual water consumption of about 300 million m^3, the potential water saving that could be achieve should only groundwater from private wells be applied to gardens would thus amount to about 90 million m^3. The potential monetary saving to the city that this represents is vast. Such saving result from the smaller amounts of water that will be pumped and treated, as well as in reducing the need to invest in new bulk water supply schemes.

The fact that Cape Town receives winter rain makes it an ideal candidate for groundwater abstraction during the dry summer months. This would relieve stress on other water sources during the dry part of the year. With winter rains the levels in the aquifer should recover, if the aquifer is not over exploited. By lowering water levels in summer storage in the aquifer is increased, which reduces the risks of flooding in some of the low-lying parts of Cape Town.

In encouraging abstraction from the Cape Flats Aquifer concern about the potential of the aquifer to meet supply will have to be addressed. Parsons (2000) quotes the estimated potential of the Cape Flats Aquifer at about 53 million m^3 per annum. If further studies show this to be correct, then the Cape Flats Aquifer has the potential to meet a significant portion of the city's garden irrigation demand. The sustainable yield of the aquifer could be increased through the artificial recharge of wastewater. Each year about 190 million m^3 is discharged to the city's rivers. Though yields vary within the aquifer, even a lower end yield of 2 m^3/hour would be sufficient to meet the irrigation requirements of most private borehole users. This means that most of the city's suburbs is in a position to abstract reasonable quantities of water from the Cape Flats Aquifer.

One concern with developing large-scale abstraction is the potential impact it may have on groundwater dependent ecosystems. Of particular concern is the impact of abstraction on wetlands that depend on groundwater discharge. A system to address this concern has been developed in Perth, where similar groundwater dependent wetlands exist. This has been done through the establishment of groundwater abstraction zones, which are classified in terms of vulnerability and recharge importance. Within sensitive zones no activities that may degrade the water quality and/or quantity is allowed. Water managers should also guard against potential degradation of water quality within the aquifer as a result of seawater intrusion or the induced inflow of poorer quality water.

Before the widespread use of private garden boreholes is initiated, an evaluation of the quality of water within the aquifer and its potential health risks will have to be evaluated. Some concern exists about the degradation of the aquifer by industrial, commercial, informal settlement and waste disposal activities (Fraser and Weaver, 2000b). It is however accepted the irrigation water quality requirements are widely satisfied (Fraser and Weaver, 2000a).

WHO SHOULD DRIVE THE CAMPAIGN?

The Department of Water Affairs and Forestry (DWAF), as custodian of the country's water resources and the City of Cape Town should promote the efficient use of garden boreholes. An important aspect in promoting private garden borehole use is public education. It is proposed that a partnership be formed with the private and public sectors as well as nongovernmental and education institutions to educate and promote the use of groundwater. Policies should be developed by the DWAF and the City of Cape Town for the use of garden boreholes that are aligned to National Water Strategies and Policies. Guidelines should also be developed for the efficient and responsible usage of garden boreholes.

Any individual who wishes to install a garden borehole should need to apply to the relevant authority for permission to install a borehole. The applicant should be legally bound to adopt an approved technical design. The technical specification would specify the depth to which a borehole may be drilled, the type of material to be used and the pump capacity (in order to control abstraction) for any particular area. A GIS database needs to be developed to spatially record data and decisions. The regulatory authority should ideally provide an advisory service, which could aid in the fostering of a good relationship with the public. After the completion of a borehole the relevant authority may inspect the completed borehole and approve its use. The data obtained during the construction of the borehole should then be loaded on the GIS database.

CONSTRUCTION

The installation of garden boreholes is fairly simple in sandy aquifers. Where the water table is close to the surface and low abstraction rates are required, shallow boreholes can often be installed using jetting. Jetting is a technique whereby borehole screens are forced into the ground using pressurized water. Percussion drilling is the favoured technique for drilling in hard rocks. This may be necessary in areas where substantial iron concretions, known as 'Koffieklip' occur. Slotted PVC casing is preferred as construction material because of its light weight, low cost and durability. Depending on the depth to the water table, the borehole may be equipped with a submersible or surface pump. The structure of a completed borehole is shown in Figure 3.

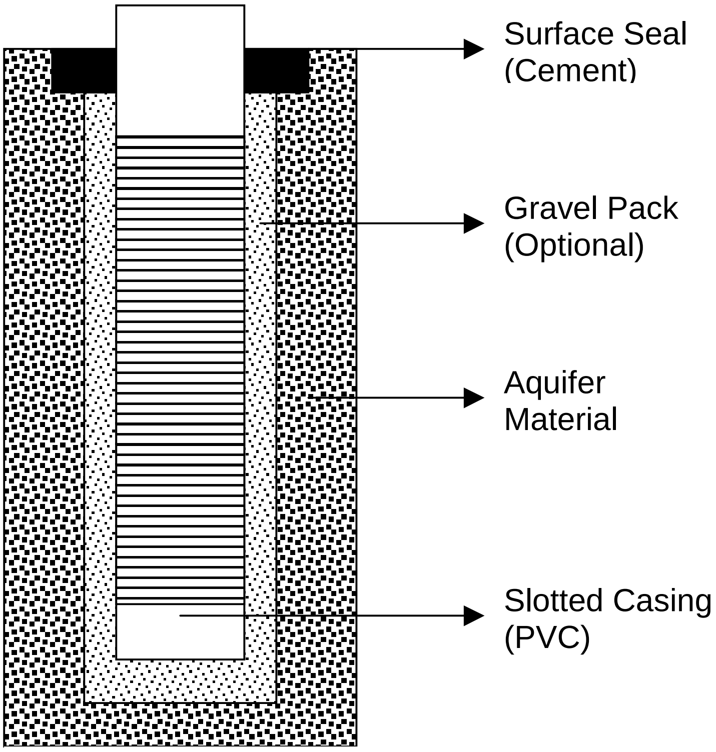

Figure 3: Typical constructed borehole in a sandy aquifer.

WATER QUALITY

The quality of the groundwater in the Cape Flats Aquifer is generally fresh due to the high recharge rates. Water samples taken from the University of the Western Cape borehole site show a fresh groundwater character in the primary aquifer and a slightly brackish water in the Secondary Malmesbury aquifer at depth (Table 1).

Table 1 Water quality of the two aquifers tapped by the UWC borehole site and from a general study.

Parameter	Primary Aquifer	Secondary Aquifer	Gen. Water Quality (Fraser and Weaver, 2000a)
Na	25.46	217.14	57
Mg	11.68	12.50	11
K	4.62	3.29	1.5
Ca	146.42	22.63	95
Si	0.37	1.09	-
Fe	2.29	0.14	-
Cl	34.50	308.15	99
HCO3	15.80	162.30	
NO3-N	0.5	2.4	<0.1
pH	4.9	7.0	7.7
EC (mS/m)	78	128	78

All values in ppm unless otherwise indicated

The quality of the groundwater is excellent, apart form elevated levels of iron in the primary aquifer. When used for irrigation the iron may result in staining on walls and pavements. The pH of the primary aquifer also has a slightly acidic nature. These two variables can cause biofouling of the screens by iron bacteria. However, with low abstraction rates the impact of this should be insignificant.

COSTS

Where geological formations are favourable and the water table occurs close to the surface, relatively inexpensive wellpoints can be constructed. By using jetting techniques contractors are able to insert PVC casing up to depths of about 20 meters. Usually the cost of such an operation, including the casing provided is in the range of R2000 to R2500. This compares well with the comparative cost of drilling a 20 m deep borehole with air-percussion drilling, which would typically be an order of magnitude more expensive. The cost of a centrifugal pump is about R 1000 (including connections and fittings). This means that a fully operational system can be installed for under R 4000. This places it within the range of many households. Lower income households however will generally not be willing to spend such an amount of capital towards garden irrigation. The experience in Port Elizabeth, where different geological conditions exist and the cost of a borehole is much higher, that private boreholes is almost exclusively found only in more affluent neighbourhoods (Lomberg, et al., 1996).

ADVANTAGES AND DISADVANTAGES

As with every scheme there are advantages and disadvantages in using garden boreholes. These are summarised in Table 2. The boreholes for garden irrigation would not require licensing but would require some form of regulation by the relevant authorities. Large-scale abstraction in coastal areas may cause salt-water intrusion, but this is unlikely due to the low abstraction rates required for garden irrigation.

Table 2: The advantages and disadvantages of garden borehole use

Advantages	Disadvantages
Savings in bulk water requirements	Initial capital layout
Long term financial benefit	Possible long term degradation of water quality from possible saline intrusion
Devolution of maintenance from service provider	Possible soil subsidence
Job creation	Possible impact on wetland systems
Research and development opportunities	More groundwater quality protection and pollution prevention required
Control water table fluctuations	

The most common fear of groundwater abstraction in urban areas is that of land subsidence. However, due to the natural groundwater level fluctuations this problem may not be very serious, but will require additional monitoring and geotechnical research. Where abstraction is low the water level stabilizes at a new equilibrium such that flow to the area of groundwater withdrawal balances the abstraction (Foster et al., 1998). Irrigation return flow would also contribute to this equilibration. The main concern would be the degradation of the water quality over time, with pesticides, herbicides or through saline intrusion.

EDUCATION

Education and information dissemination should form an integral part of such a scheme. The main focus would be on water conservation awareness as well using the garden boreholes responsibly.

Sensitising all role players on the importance of groundwater and the positive role it can play in water conservation and demand management must play an important role. In Perth educational units have been set up to run public campaigns in water resource education targeting schools and the general public through ad campaigns (print and electronic media), competitions and sponsorships.

The promotion of water wise gardening, including irrigation during periods of low evapotranspiration (early mornings or just before or after sunset), drip irrigation and/or water saving sprinkler systems, would help in preventing over exploitation of the Cape Flats aquifer.

CONCLUSIONS

The first step in encouraging widespread private garden irrigation would be through the building a public awareness of the value of groundwater. The experience of Perth in public education could provide water managers in Cape Town with insight on how to proceed with this. The use of private garden boreholes will strengthen the city in its development of an integrated approach to water resource management. It is envisaged that the use of private boreholes for garden irrigation will form part of a larger education and water saving programme. Complimentary water saving initiatives should also be encouraged such as rainwater harvesting and the installation of water saving devices.

The idea of using groundwater resources is normally a progressive process that may take many decades (Foster et al., 1998). Financial incentives for the installation of garden boreholes and efficient water use may be required. Among the bigger challenges introduced by private garden irrigation is the difficulty in exerting some degree of control over the large numbers of small-scale abstractions.

If such an initiative is to work it will require the political and social will of the city's managers and the general public. The idea of using garden boreholes is attractive but will require more investigation to determine its feasibility and affordability. It is recommended that a more comprehensive study be launched to determine the feasibility of using garden boreholes for irrigation

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Why water is not an ordinary economic good, or why the girl is special

Hubert H.G. SAVENIJE

IHE-Delft, P.O. Box 3015, 2601 DA, Delft, The Netherlands

hsa@ihe.nl

ABSTRACT
Water is not a normal economic good. It has a large number of characteristics that distinguish it from other goods. Individually, these characteristics may not be unique, but the combination makes water a special economic good. As a result, the application of regular economic theories to water resources management is not very efficient.

Keywords: *water as an economic good; water resources management*

INTRODUCTION

Water is an economic good. Since the Dublin Conference on Water and the Environment in 1992, this notion is widely accepted among water resources managers. Besides being directly consumed by humans, water is an important production factor, in the broadest sense, and it is scarce. Hence it is an economic good. The difference of opinion does not lie in this fact, but in the interpretation. Some people, mostly water professionals, claim that water is special, others, mostly economists, claim that water is not different form any other economic good: "There is a demand for it, there are operators that make it available (supply), it has a value. The price should reflect the value in order to achieve efficient use of the resource. A water market is an effective instrument to reach efficiency of allocation". Water professionals maintain that it is not that simple. Economists maintain that water professionals fail to see the larger picture because they are inhibited by their detailed knowledge of the subject. Much like the father who refuses to see that his daughter is just a girl.

In this paper an effort is made to present an overview of the arguments why water is not just another economic good. The paper is meant to open a dialogue. It is not meant to be provocative or overconfident, rather it is meant to explore ways of bringing water professionals and economists together and to find a way through the misunderstandings that appear to exist. As a water resources manager discussing economics, I probably use the wrong terminology in some places or misinterpret certain definitions. I hope the reader can see through these lapses and doesn't hesitate to correct me where I'm wrong.

WHY THE GIRL IS SPECIAL

Water has a combination of characteristics that make it different from any other good. Individually, these characteristics are maybe not so restrictive, but in combination they make that water has to be dealt with in a very special way. The following characteristics are relevant in this context:

1. water is essential
2. water is scarce
3. water is fugitive
4. water is a system

5. water is bulky
6. water is non-substitutable
7. water is a complex good

WATER IS ESSENTIAL

There is no life without water, no economic production, no environment. There is no human activity that does not depend on water. It is a vital resource. This maybe makes water special, but not unique. The same can be said about air, land, fuel and food (see Table1).

WATER IS SCARCE

The amount of water available is limited by the amount of water that circulates through the atmosphere on an annual basis. All the water stems from the rainfall. The amount of rainfall that falls on the continents is finite. But not all that water can be used. It is unequally spread in space and time and large parts of the world experience shortages during certain periods of time.

WATER IS FUGITIVE

Until now, there is not really a problem. A good that is scarce and essential is the perfect example of an economic good. However, water is fugitive. The water flows under gravity. If we don't capture it, it's gone. The availability of the water varies over time, and so does the demand for water. It flows through our fingers unless we store it. Water is different from air and land, because these goods don't need to be stored: they are stocks, whereas water is essentially a flux. There are of course also stocks of water: groundwater aquifers and natural lakes. But these lakes and aquifers only can be used sustainably if they are replenished by the flux. The stock is small compared to the flux. Of course we can store water artificially, but also then, the stock is small as compared to the flux. You need annual recharge to make the water available. It is not like fossil fuel where stocks are huge compared to the annual flux.

WATER IS A SYSTEM

The annual water cycle from rainfall to runoff is a complex system where several processes (infiltration, surface runoff, recharge, seepage, re-infiltration, moisture recycling) are interconnected and interdependent with only one direction of flow: downstream. If you interfere upstream, there are downstream implications, externalities and third party effects. If you withdraw groundwater from an aquifer, further down in the cycle, at some later point in time, there will be less water in the river, which some other user was relying on. If you discharge waste at some point, damage is incurred somewhere downstream. A catchment is one single system and not the sum of a large number of subsystems, that can be added-up or optimised in a regular economic model.

WATER IS BULKY

Now all of the above would not be a problem if we could transport the water easily from one place to another as we do with fuel or food. Then we could move water from an area of access (the mine) to an area of shortage (the user). This process could cater for fluctuating water needs that vary both over time and space. We could also transport water from downstream to upstream, as we do with normal economic goods. A water market could solve that problem easily and efficiently. But besides exceptional cases, this is not done. Why? Water is too bulky. A domestic or industrial water user is willing to pay about 1$/$m^3$. A farmer is seldom able or willing to pay more than a small fraction of that amount. Other economic goods are much more expensive than that. Fuel costs about 100$/m^3 and food in the order of 200$/m^3. A factor 100 more than the value of domestic water and at least a factor 1000 more than the agricultural value of water. Unfortunately there are no ways to condense water, as is done with orange juice, for instance. To transport orange juice, producers first make a juice concentrate, which after transport is again diluted with water.

WATER IS NON-SUBSTITUTABLE

What we do with orange juice cannot be done with water. Water can only be diluted with water to turn it into water. Although other economic goods have alternatives, water has not. For fuel, one can choose between oil, gas, coal, wood, hydropower or solar power. For food one can choose between bread, pasta, rice, or maize. But what alternatives are there for water: rainwater, groundwater, surface water, …? It's all the same water from the same system, from the same source. There is no alternative, there is no choice.

WATER IS NOT FREELY TRADABLE

Hence we are looking at a good that is essential, but too bulky to be traded over large distances. The consequence is that we should use it when and where it is available. There is no other economic good that has this complicated combination of characteristics (see Table 1), turning it difficult to be traded freely (except in exceptional cases, such as with bottled water, or when two neighbouring parties can make use of the same water intake). Water markets can only function if they are very localised and take account of the fact that water flows downstream (e.g. in a micro-catchment or within a subsystem, such as an irrigation project). World-wide, water is traded in the form of its products: grains, timber, meat, fodder, fruits, flowers, etc. This is called the trade of "virtual water", where one kg of produce roughly corresponds with one m^3 of water (a condensation with a factor 1000). It is easy to show that it is more attractive to trade the products than the water. This applies to the international situation, but also nationally and within a river basin. Food should be grown in places where land and water (particularly rainfall) are abundant. It's only for political reasons that food is grown in water scarce areas. Hence it is more useful to think about a free and open food market rather than a free water market.

WATER IS COMPLEX

Although the above conclusion that water is not freely tradable is the most important argument to give water a special treatment, there are a number of additional aspects that make water complex with regard to other economic goods. Economists would say that all of these aspects can be dealt with, but the fact that there are so many complications makes water at least very special.

1. Water is a public good. This is a consequence of water being essential, scarce and non-substitutable. It is the responsibility of governments to make sure that there is safe access to water (for domestic and other economic uses) and that society is protected from water related hazards. It is of course not the responsibility of governments to provide water related services for free, a misinterpretation often made.
2. Water is location bound and it crosses administrative boundaries. Most of the world's water resources are part of international river systems, and even if they are national, they cross provincial or state borders. As a result there are different authorities that are responsible for the supply and demand of these waters, which is always a complicating political factor.
3. There are high production and transaction costs involved, even when gravity is used to transport water. For water re-allocation one requires diversion structures, pumps, boreholes, canals,

pipelines, dams, reservoirs, etc. These structures are expensive to build, maintain and operate. Metering and billing is complex. This aspect is related to the bulky character of the water.

4. The market for water is not homogeneous. Some users have a high willingness to pay, consuming small amounts of water (domestic users, industries), others have a low willingness (and ability) to pay and use large amounts of water (farmers), yet others have no ability to pay (environment, poor people). They cannot be merged into one market. Although the water is the same, the character of the demand is different in terms of quality, reliability and the quantities involved. Trade-offs between these different user categories should be made through political priority setting, not through the market. Within one of these categories economic principles can be used to determine a proper water price, but between sectors this is not useful.
5. There are macro-economic interdependencies between water using activities. Water use in agriculture affects industry, services, etc. Since water affects all economic activities, the relations are complex. This can be dealt with, but it is a complicating factor.
6. There is always the threat of market failures in water supply. Partly this is caused by the fact that water is bulky. To reach economy of scale, large investments are required, which lead to natural monopolies in virtually all water services: hydropower supply, drinking water supply, irrigation, drainage, sewerage, flood protection, navigation, etc. Water works have the character of public infrastructure, where there is a choice between a state monopoly or a private monopoly. Only for urban water supply there are examples of successful privatisation processes, but these are also complex and highly demanding in human capacity for control.
7. Water has a high merit value, often not expressed in monetary terms. Water relates to our perception of beauty, wellbeing and health. People like to live in the proximity of water, which should be clean and aesthetic.

THE DRINKING WATER BIAS

Why is this message so difficult to convey? I fear that much of the confusion about the economics of water stems from the fact that people assume that the water issue is merely about drinking water, and particularly about urban water supply. We also see this in the media. If we want to draw the attention of the public to water issues, we use the image of a child or a woman near a water point. Although the drinking water and sanitation issue is one of the largest societal challenges of the next century, it is a minor issue with regard to global water scarcity. The main issues in terms of water resources allocation are water for food, water for nature, sustainable use of water resources, closing water and nutrient cycles, water resources management in mega-cities, options for non-water borne sanitation, flood management, etc. These issues are of high societal importance, requiring substantial investments. And hence they are essential parts of economic planning. Yet they have nothing to do with the classical interpretation of water as an economic good. It is this (urban) drinking water bias which leads people to believe that water is just another economic good. In this paper, I hope to have shown that within the urban water supply sub-sector this may be true, but that as soon as we zoom out to the wider field of water resources management the concept needs to be interpreted much more widely.

CONCLUSION

Water is an economic good, but it is not a normal economic good. A large number of aspects of water have been mentioned that form the motivation of this statement. Although individually these aspects may not be exceptional, their combination makes water a very special good. This implies that in the allocation and the use of the water we have to take a complex set of economic interests into account. These are multi-sectoral, multi-objective and often non-monetary. The character of water is unique. It does not allow the application of market theory to the allocation of water between sub-sectors and different water using categories. Within a sub-system, or even within a sub-sector economic pricing may be a useful tool to reach efficiency, but allocation efficiency at that scale is only a minor problem in view of the major global issues that the water sector is facing. Water markets are not useful beyond the very localised scale of a micro-catchment, an aquifer or an irrigation system. It is too bulky to be traded over large distances or against the force of gravity.

Table 1. Aspects of water and how they apply to other goods

	water	air	land	fuel	food	observations
essential, vital	+	+	+	+	+	
scarce, finite	+	0	+	+	+	finite, high demand
fugitive,	+	0	0	0	0	fluxes versus stock
indivisible	+	0	0	0	0	it is a system
bulky	+	+	0	0	0	virtual water trade
non-substitutable	+	+	+	0	0	
public good	+	+	0	0	0	
location bound	+	0	+	0	0	
high mobilisation costs	+	0	0	0	0	
non-homogeneous market	+	+	+	0	0	
prone to market failure	+	0	0	0	0	
merit value	+	0	+	0	0	health, beauty, culture

Water Demand Management and tourism in arid countries – lessons learnt from Namibia

Klaudia SCHACHTSCHNEIDER

Ministry of Agriculture, Water and Rural Development, Division: Water Environment,
Private Bag: 13193, Windhoek, Namibia

schachtschneiderk@mawrd.gov.na

ABSTRACT

Namibia's aridity is forcing its decision-makers to resort to new water resource management approaches, including Water Demand Management (WDM). Such a change in management approach is facilitated through the country's opportunity at Independence to rewrite and adapt its old policies, including those for Water and Tourism. Old water-related policies in Namibia and South Africa have created a perception among the public that it is government's responsibility to provide water cheaply and in unrestricted quantities. The biggest challenge within WDM is to change the perceptions of society about the value of water and to instil a feeling of responsibility towards the resource as a whole. Legal support for WDM in form of the new Water Act is a crucial platform from which to plan the practical implementation of WDM throughout Namibia. In order to be able to put the policy into practice, it is imperative to understand which driving forces motivate people to adopt WDM initiatives. Within the Namibian tourism industry three main driving forces have been identified which motivate managers of tourist facilities to implement WDM. This paper discusses how decision-makers can build on these driving forces in order to achieve increased water use efficiency in the tourism sector. Furthermore, how the relevant policies, the Water and Tourism Policies, can complement each other in order to achieve mutual goals, such as sustainable use of scarce natural resources.

***Keywords*:** *Water Demand Management; tourism; driving forces; policy*

INTRODUCTION

In the past Namibia, like South Africa and many other arid developing countries have followed the typical path of ensuring a water supply which always exceeded the water demand with the help of technical and engineered solutions. The old South African and Namibian Water Acts supported the provision of cheap access to water for most citizens, leading to a general perception among the public, especially outside Municipal boundaries, that it is the governments duty to provide water as a cheap and abundant commodity (Turton, 1999). This lack of respect for the value of water in an arid country like Namibia can result in an inefficient and unsustainable water demand, especially if development needs and population growth create a constant increase in water demand as well. Opportunities to develop new supply-sided solutions, such as dams, water transfers and desalination plants are limited and extremely expensive.

Namibia's Independence in 1990 has provided a unique opportunity to write new and to adapt old policies and acts, including the Namibian Water Act and a new Tourism Act. Currently Namibian decision makers attempt to increase water use efficiency by making Water Demand Management (WDM) an integral part of the new Water Act.

Legal support for WDM in form of the new Water Act is a crucial platform from which to plan the practical implementation of WDM throughout Namibia. In order to put the policy into practice effectively, it is imperative to understand which driving forces motivate the different water use sectors and their people to adopt WDM initiatives.

Water Demand Management (WDM) is a broad concept with many definitions. In this paper it is defined as: A management approach for the water sector and user stressing the efficient use of existing supplies, rather than developing new ones, with the help of policies, ethical, economic, educational and technological means (van der Merwe, 1999).

BACKGROUND

Namibia's water and tourism

Namibia is a semi-arid to arid country with low, seasonal and variable rainfall that is below 20 mm along the west coast to 600 mm per annum in the far North-east. Annual evaporation rates exceed rainfall by up to six times. As a result Namibia's water supply relies on the limited available surface water and groundwater sources. Currently, the available surface and groundwater sources are almost fully exploited (Bethune, 1996).

Tourism is the fourth largest and fastest growing sector of the Namibian economy (6 – 9 % per annum) with a 7% contribution (N$ 1.3 Billion in 1998) to the GDP. A quarter million tourists made use of Namibian tourist facilities in 1999 and approximately 25 000 Namibians are employed in the sector (Minister of Environment and Tourism, 1999).

Tourism uses less than 1 % of Namibia's available water, whilst agriculture (irrigation and livestock) uses 61% (Lange, 1997). Improved water use efficiency in tourism will only have a comparatively small impact on Namibia's overall water use. However, many tourist facilities lie in particularly arid and ecologically sensitive areas where effective resource management (including WDM) is crucial to ensure sustainable tourism operations (Schachtschneider, 2000).

Namibia's Tourism Draft Policy

In the past Namibia's tourism was developed around large scale, self catering, state owned resorts in protected areas. With independence the numbers of private and communal tourist operations have grown markedly, catering for different clientele. The Tourism Policy for 2000 to 2010 is currently being drafted. In its present form it is pointing out that there is evidence of natural resource over-utilisation within Namibia's tourism industry. On account of the countries fragile resource base, the draft policy seeks to encourage stakeholders to develop high quality, low impact tourism. This would mean the exploitation of specialist tourist niches for few but high paying customers.

One such niche would be proper 'ecotourist' destinations, who provide a natural and educational experience to few, high paying guests and who usually operate in very scenic and sensitive areas.They integrate sustainable resource use in their marketing strategy, which provides them with unique business opportunities, allows guests to have a unique 'nature' experience and ensures efficient natural resource use within the operating area.

Namibia's Water Policy

The South African Water Act 54 of 1956 is still used in Namibia today. A new Water Act more suitable to Namibian circumstances is nearing completion. This Act will be based on the recently accepted National Water Policy (2000).

The new Policy supports the implementation of WDM implementation in that:

1. Government will be the custodians of all water resources and will have the right to control all water use and disposal
2. Integrated supply and demand planning is required in both the short and long term
3. The Policy promotes sustainable water utilisation through appropriate pricing, promotion of water efficient technology, public information and awareness programmes, information sharing and co-operation between parties, the promotion of wastewater reuse and active support of research and data gathering on water conservation
4. Consideration is given to the establishment of an environmental reserve.
5. Catchment management is provided
6. The establishment of Namibian water quality standards will be very important for wastewater reuse.

Until the new Water Act is in place it is difficult to enforce WDM principles since there is no control over borehole numbers or water abstraction in most of Namibia. The only controlled areas relevant to tourism lie within Municipal boundaries or nature reserves. The old Act does not support WDM initiatives and nobody outside municipal boundaries is required to use water efficiently, thus the drive to implement WDM principles in tourism and other industries is currently not backed or enforced by law. At the moment one can only appeal to businesses to use water more efficiently. In the tourism sector the best voluntary support has come from 'ecotourist' facilities that include efficient resource use as part of their marketing strategy.

WDM and Tourism

The Water Demand Management Study of Namibian Tourist Facilities is a three year project run by the Ministry of Agriculture Water and Rural Development and supported by the Water Research Fund for Southern Africa (WARFSA). The 1999 baseline study looked at water use in different kinds of tourism establishments, including hotels, large scale resorts, lodges, community camps and so-called 'ecotourist' camps.

Results showed that community camps and ecotourist camps used the least water, often due to lack of water in the area, basic infrastructure and a sustainable management approach. Big resorts and luxurious lodges spent between 15 and 175 times more water on every guest than community camps and ecotourist camps (Schachtschneider, 2000).

In 2000 and 2001 the study looked at the implementation of WDM initiatives in the form of technology, awareness and management approaches at six study sites representing the different kinds of tourist facilities, i.e. lodges, resorts, urban facilities, community camps and ecotourist camps. Table 1 explains the differences between the study sites.

All project study sites received a list of recommendations on site specific, feasible WDM approaches, that could improve their water use efficiency. All study sites co-operated on a voluntary basis with the project and the project researcher acted as a facilitator for the implementation of the recommended approaches. Management at each study site was given the responsibility to decide which of the recommended WDM approaches to implement and which to ignore or postpone. Each study site (excluding the ecotourist sites, because they had implemented all suitable WDM steps themselves at the outset of their operation) chose to implement different kinds and amounts of WDM initiatives.

Since the project only observed and acted as a facilitator for WDM implementation, the project itself created an enabling environment to implement WDM, but it did not enforce any implementation. The project fieldwork was concluded with management interviews at each site, to find out what drove them to support and implement WDM. The answers were compared with fieldwork observations. Three driving forces were identified: external controls, economics and ethics.

Table 1: Description of study sites

CATEGORY	DESCRIPTION	SITES
COMMUNITY CAMP	Basic, small scale, affordable, camping outside Municipal area, on communal land, basic water supply, little water use, few staff live on site, limited water supply,	Spitzkoppe Community Camp
RESORTS	Large scale, ranging from camping to economy and VIP accommodation, outside Municipal area, often in Nature Reserve, large scale water supply, high water use, staff live on site	Bernabe de la Bat Resort
URBAN FACILITY	Range of accommodation Economy – Luxury inside Municipal area, urban, hotel, pension or self catering Municipal water supply connection, no staff live on site,	Swakopmund Municipal Bungalows
LODGES	Luxury accommodation for few, high-paying tourists outside Municipal area, on private land well-established, small scale water supply, staff live on site	Ongava Lodge
ECOTOURIST CAMP	Upmarket or comfortable basic accommodation for few guests, situated in sensitive environment, daily management according to sustainable resource use principles, planned and constructed with resource use efficiency in mind	Skeleton Coast Camp Etendeka Camp

External controls comprise the aridity of the area (and the inherent lack of water) as well as imposed restrictions by either a municipality or another external controlling body, such as the Ministry of Environment and Tourism if the facility operates in a nature reserve. Ethics is the amount of environmental sensitivity inherent in the facilities' business and management approach. Economics is the cost of water, calculated as the full supply cost for this project.

Each site found one or the other driving force more important and the amount of WDM implementation varied accordingly. The location of each study site is shown in Figure 1.

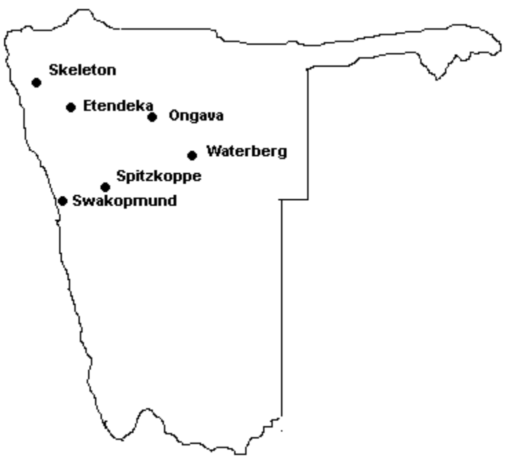


Figure 1: Map of Namibia with the six tourist facilities

RESULTS:

Etendeka Mountain Camp and Skeleton Coast Camp

The two sites are very similar in their setup, approach to water use and their water availability. Both cater for few, high paying guests. They were monitored by the WDM project, not to improve their water use, but as show cases, where water use efficiency has been perfected.

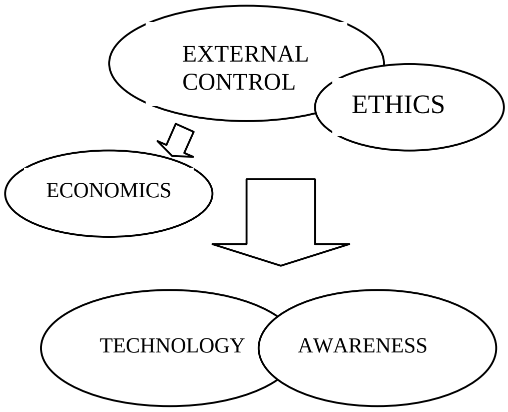


Figure 2: WDM driving forces of Skeleton Coast and Etendeka Mountain Camps

The Skeleton Coast Camp is situated in the extremely arid Namib desert, obtaining less than 20 mm of average annual rainfall. Since it is situated in the Skeleton Coast Nature Reserve, the Ministry of Environment and Tourism controls their water consumption. As a result of the lack of water in the area all water is transported to the camp by vehicle, pushing up the total supply cost to a phenomenal N$ 271 (U$ 32.00) per cubic metre. Due to the luxury level of the camp, it is possible to integrate the water cost into the guest fee, making it a slightly less important driving force than external controls or ethics.

Etendeka Mountain Camp is situated in a dry area with approximately 150 mm of average annual rainfall. The water scarcity is the main driving factor for WDM at Etendeka. Water also has to be transported by vehicle, making the total cost recovery price N$ 200 (U$ 24) per cubic metre. Like Skeleton Coast, the water cost is integrated into the guest fee, making it less of a driving factor.

Both enterprises follow strong ‘ecotourist’ principles by operating with minimal environmental impact through efficient and appropriate resource use. The facilities were planned and constructed with water efficiency in mind. The number of water outlets is minimised and piping is standardised in order to make maintenance and spare part storage easier. WDM incentives include technical WDM solutions such as wastewater reuse, the installation of low flush toilets, water efficient showers and kitchen taps, the absence of pools and watered gardens. Laundry is transported off the premises to be washed elsewhere. Leak losses are minimal due to strict maintenance controls. Management encourages all visitors and staff to minimise their water use through talks and comprehensive notices. All these measures ensure that Skeleton Coast and Etendeka use no more than 1.5 cubic metres of water on a fully occupied day.

Spitzkoppe Community Restcamp

The Spitzkoppe Community Camp lies at the edge of the Namib and receives very unreliable rainfall of less than 100 mm per annum on average. Since 1992 the Spitzkoppe community has ventured into the tourism market in order to broaden their income opportunities.

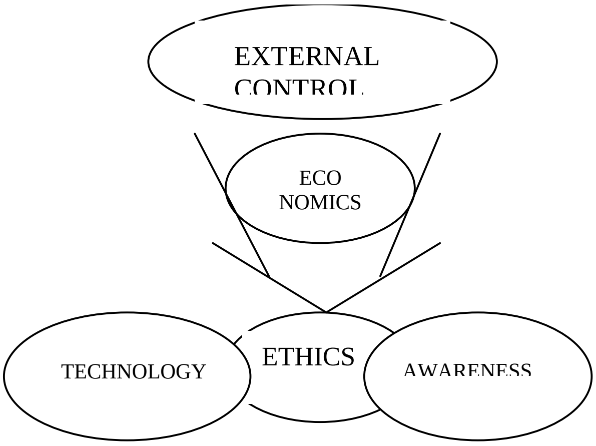


Figure 3: Spitzkoppe Community Camp driving forces

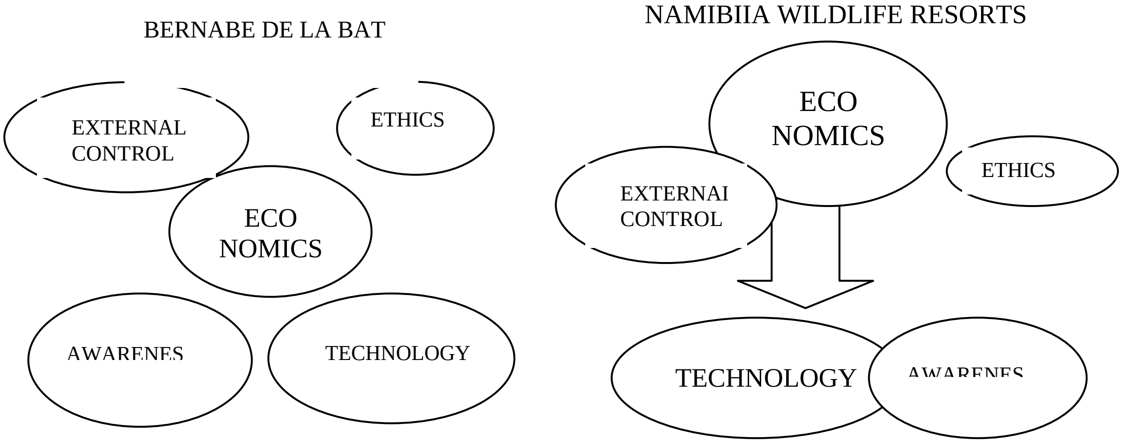
Water is extremely scarce in the Spitzkoppe area, making it the most important driving force. The tourist camp with its 28 camping sites and two bungalows obtains a rationed amount of 5 000 litres of water per month from the nearby village desalination plant. The rest of the water is brought along by visitors.

The subsidised supply cost of water to the community camp is minimal (N$ 2.75, U$ 0.33) per cubic metre. When looking at the billed supply costs alone, the camp staff do not regard the cost of water as a great driving force, but when looking at the total supply cost (including capital costs and maintenance), the cost of water is substantial at N$ 56 (U$ 6.67) per cubic metre.

For the community members WDM is part of everyday life. They cope with the 5 000 litres by doing leak control, selling water to tourists, promoting water imports by visitors and appropriate technological incentives which include dry sanitation and bucket shower systems.
While they are very knowledgeable and innovative about water use efficiency, WDM is not inherent in their business ethic. Should the water supply ever increase, the additional water would be readily used, irrespective whether it is sustainable to the area.

Waterberg

The Bernabe de la Bat Resort is operated by the company Namibia Wildlife Resorts and it is situated in the Waterberg Plateau Park, a nature reserve. The importance of driving forces differed between the Bernabe de la Bat Resort and the overall company.



Figures 4 and 5: WDM driving forces at Bernabe de la Bat and Namibia Wildlife Resorts

Bernabe de la Bat has vast amounts of spring water at their disposal, which is unmonitored. There are no external controls driving the implementation of WDM. Staff and management living on site regard water as a cheap and readily available commodity and WDM as unnecessary. The total cost recovery price per cubic metre at Bernabe de la Bat is less than N$ 1 (U$ 0.12) per cubic metre, providing no economic driving force either. As a result almost no WDM approaches were implemented over the study period.

While the project efforts were unsuccessful at Bernabe de la Bat, top management adopted some of the WDM recommendations and applied them at other resorts. A combination of mainly economic and sometimes external controls (water scarcity) drove the company to adopt WDM approaches, such as awareness materials, improved maintenance and water saving/reuse technology. The company Namibia Wildlife Resorts does not yet have a company ‘Environmental Management Plan’ or ‘Environmental Statement’ to drive WDM, therefore ethics play only a minor role.

Swakopmund Municipal Bungalows

The Swakopmund Municipal Rest camp is a self-catering accommodation situated in the desert coastal town of Swakopmund. The rest camp has 193 bungalows with a maximum capacity of 960 beds.

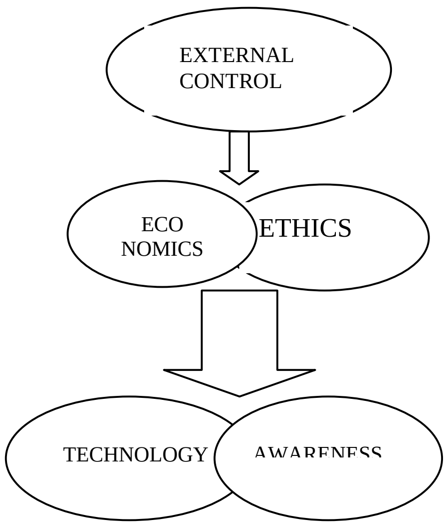


Figure 6: WDM driving forces of the Swakopmund Municipal Bungalows

Swakopmund lies in an environmentally sensitive area and is facing severe water scarcity, which is the main driving factor for WDM. It has resulted in the Town Council adopting an environmental statement and an environmental conservation committee. The committee promotes the improvement of environmental conditions and supports environmental awareness campaigns and research. Water use efficiency is regulated with the help of block tariff systems that discourage water wastage (N$ 5-9, U$ 0.59-1) per cubic metre. Different WDM approaches, including regular water awareness campaigns and innovative supply solutions, including desalination and semi-purified effluent reuse for gardening are part of the Swakopmund Town Council strategy.

The Swakopmund Municipal Bungalows fall directly under the Town Council and adopt the same approach to WDM. They pay a municipal rate of up to N$ 5 (U$ 0.59) per cubic metre for their water use and are forced to maximise their water use efficiency for business reasons. They do it by monitoring their daily water use, reusing wastewater for landscaping, implementing water saving devices such as low flow shower heads, running a very strict maintenance control system and distributing awareness materials for visitors.

Ongava Lodge

Ongava Lodge is a luxury lodge for 20 guests, situated at the western border of the Etosha National Park in an area with an average 400 mm annual rainfall. Ongava Lodge is run by the company 'Wilderness Safaris' on a private 29 000 hectare game reserve.

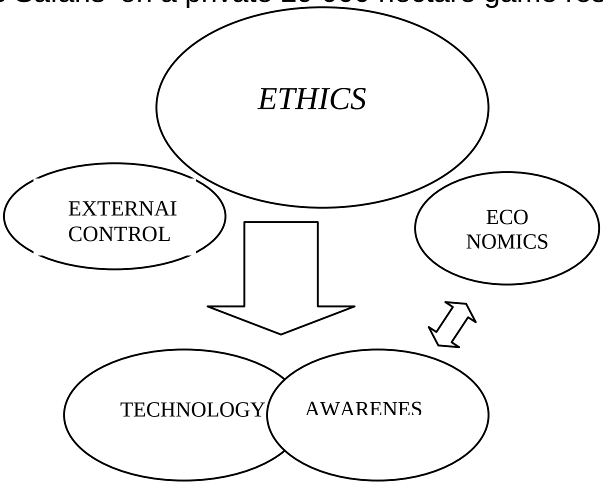


Figure 7: WDM driving forces at Ongava

Ongava Lodge is responsible for its own water supply. It has a sufficient and stable groundwater supply, so there is no imminent local water scarcity. Ongava Lodge pumps its own borehole water and the total supply cost is only N$ 3 (U$ 0.36) per cubic metre. Water costs are therefore no important driving factor either.

However, Ongava lies in a relatively dry area and sells the 'wildlife' experience to guests. Wilderness Safaris operates in many such areas, therefore the efficient and sustainable use of resources is part of the international company strategy. This approach is actively promoted by top management and is embraced by local management and staff members. This strong ethical feeling to use natural resources sustainably has led to the implementation of several WDM steps. They include an intensive maintenance programme, the replacement of lawns with more suitable indigenous vegetation, implementation of evaporation control, suitable technical devices and awareness material for visitors in the form of notices and talks.

DISCUSSION

The case studies have shown that WDM implementation differs within the Namibian tourism industry due the presence or lack of three driving forces:

1. External Controls - the level of water scarcity and levels of control over water use by a separate body (MET or town councils) in the operating area
2. Economics - the cost of water, depicted here as total cost recovery
3. Ethics - perceptions of staff and management concerning the value of water and resultant attitudes towards WDM initiatives

WDM is most effectively implemented where all three driving forces play an important part, as shown by the Skeleton Coast, Etendeka Camp and Swakopmund examples. Usually a local water scarcity directly influences water costs and the management approach of the facility. Where none of the driving forces are considered important, WDM is not implemented (Bernabe de la Bat). As shown by the Ongava case, strong ethics is a driving factor apart from local water scarcity which can induce WDM implementation in the absence of other driving factors. Many tourist facilities in Namibia are not facing imminent water scarcity and they would need another driving force to make them implement WDM initiatives.

While the right attitude towards WDM is a powerful driving factor on its own, it unfortunately is also the most difficult to implement on a national scale, since there is no common approach or recipe to change attitudes of individuals. Especially in Southern Africa WDM faces its greatest challenge in changing perceptions that have been engrained by inappropriate past policies and the provision of free water.

For the sake of WDM implementation in the Namibian tourism sector, decision makers should build on the power of all three driving factors and ensure that all tourist facilities are compelled to reduce their water use, receiving pressure from the economic, external control and ethical driving forces.

New policies can complement one another to reach common goals and help to overcome past policy shortcomings. The Water Policy promotes the implementation of WDM, while the Tourism Policy promotes the idea of specialised tourism with low numbers and high profitability. The case studies have shown that so-called 'ecotourist' sites use very little water and are water efficient. Close co-operation of the water and tourism sectors can ensure that the development of such appropriate facilities receives preference to less sustainable and larger ones in the future.

Policies and Acts can directly impose external controls on the tourism sector. The Tourism and Water Acts can jointly support the changing of the Namibian Building Standards, enforcing appropriate technology implementation and water efficient construction at new tourist enterprises. The changing of Building Standards will additionally provide a marketing opportunity for Namibian entrepreneurs to expanded the efficient technology market and to ensure a selection of appropriate, suitably robust, affordable and reliable devices country-wide.

Both Acts could influence the ethical driving forces by supporting an environmental award for the facility with the most sustainable resource use (including water, energy and waste management). Such an award will serve as a positive reinforcement tool for those tourist facilities interested in sustainable resource management. The Acts could cover an even greater percentage of tourist facilities if sustainable resource use became an integral component of the tourism grading standards. It would force every existing tourist facility to adopt more efficient resource use practices if they want to be eligible for grading. The grading system needs to be considerate towards differences in design and age, which can make the implementation of WDM initiatives difficult.

A lot of focus needs to be placed on awareness, which can minimise water wastage through appropriate maintenance schemes, visitor awareness and appropriate staff behaviour at all facilities. The Namibian National Water Awareness Campaign has produced awareness material for the past nine years, informing the public of the national realities of water scarcity and promoting a change of attitude towards water both as a resource and as a habitat for wildlife. While increased awareness does not imply an immediate change of attitude, the awareness campaign is a valuable national tool to contribute to the ethical WDM driving force.

The new Water Act itself will provide government with more power over Namibia's water resources, making it possible to exercise control over water use at different sites, provided that the necessary manpower is available to do inspections. Negative enforcement in the form of fines and permit refusals would be an option when faced with a severe offender. When interviewed, management admitted that this option is extremely unpopular, however, they agreed that it is a very effective and necessary method to enforce appropriate behaviour.

Finally, the Water Policy promotes appropriate pricing for water use. Payment for water can hardly be enforced throughout Namibia's tourism sector due to the lack of manpower and the sheer number and spread of the facilities. Internal water efficiency could be improved at facilities by metering resident staff water use and charging them a fair price that will encourage water saving behaviour. The money could be led back into a staff water supply maintenance budget.

CONCLUSION

Since Independence, Namibia has had the unusual opportunity to rewrite and adapt old policies which are no longer practical, including the Water and Tourism Policies. The aridity of Namibia has forced decision makers to adopt new water resource management approaches, including water demand management in the new Water Policy. Legal support for WDM in the form of policies is a crucial cornerstone to implement WDM country-wide, but it is equally important for decision makers to understand the main driving forces that motivate people to adopt WDM initiatives if the new policies are to be put into practice effectively. Within the Namibian tourist industry, the three driving forces were identified as external controls, economic reasons and ethical principles.

When the new water policy is put into practice, the power of all three driving forces needs to be taken into consideration. The new Tourism and Water Laws can complement each other to achieve a mutual goal – to support environmentally sustainable tourist facilities which cater for few, high paying visitors, since such facilities have proved to be the most profitable and sustainable within the Namibian tourism industry.

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An Integrated Process-Based Water Valuation Model

Ismail SEYAM[1] and A.Y. HOEKSTRA

International Institute for Infrastructural Hydraulic & Environmental Engineering, Delft, The Netherlands

[1] seyam@ihe.nl

ABSTRACT

Water valuation has been recently recognized as an important key for sustainable water management. Although there is a sizable knowledge available for valuing natural resources, water has unique characteristics that need to be integrated with water values. A certain water particle can be used several times for various purposes before it is lost from the water system. Thus, in a water system, multiple benefits can be generated by the same water at different locations, different times and for different purposes. It follows that the value of water is inseparable from its path within the water system. Among the diverse values of water, many have large temporal and spatial scales, which hardly fit the temporal and spatial scales of water processes. The main goal of this paper is to illustrate the connection between in-situ water values and the dynamics of the natural water system through the development of a water valuation model for the Zambezi Basin. The application makes use of an available water resource model for the Zambezi, AQUA, and of in-situ water values estimated for the main water using sectors. In order to overcome the difference in temporal scales between water values and water processes, annual water values are dis-aggregated into monthly values, thus making it possible to link water values with water resources models of monthly time steps. The Zambezi basin is schematized as the outcome of intersecting national boundaries and sub-basins as a compromise between the spatial scale of water values and water processes. The application shows that providing a dynamic connection between water values and the natural system makes it possible to analyze the effect of certain changes in the natural system on the value of water flows. It also offers an insight into the interaction between water values and the uneven availability of water within a particular year.

Public participation in setting the goals for integrated water resource management: a means to equity and sustainability?

Tamsyn SHERWILL[1] and Kevin ROGERS

Centre for Water in the Environment, School of Animal, Plant and Environmental Sciences, University of the Witwatersrand, Private Bag 3, WITS 2050.

[1] tamsyn@gecko.biol.wits.ac.za

ABSTRACT

South Africa's new national water policy introduces the requirement for proactive water resource management, which is driven by societal goals – meeting stakeholder needs and values in an equitable and sustainable way. Stakeholders are required to reach agreement on the 'desired state' of a particular resource, as represented by the combination of Ecological Management Classes for different river reaches, and the Ecological Reserve that is set to achieve this. The resulting requirement for ecologists and engineers to interact with stakeholders is both new and challenging. This paper investigates the interaction of these technical and social aspects of a 'desired state' process. The ideas presented have been developed through a variety of experiences: workshops held with stakeholders from the Inkomati Water Management Area, observation of the DWAF's participation processes in various catchments, and ongoing interaction with other researchers and practitioners in this field. A variety of approaches may currently be adopted in conducting the prescribed participatory processes. These range from chiefly top-down, technocratic, and product-oriented procedures, to a more bottom-up, process-oriented and flexible approach. A key distinction lies in the way stakeholders' needs, values, perspectives and preferences are elicited and incorporated into the decision-making process. Consulting various interest groups separately, whose preferences are then combined in 'optimal', compromise scenarios, will fail to achieve the 'buy-in' and inter-sectoral cooperation required. The participation process is instead a vital means toward achieving the 'co-evolution of stakeholder preferences' toward a shared vision and consensus decision. It is more important that participants talk and listen to each other, rather than to a facilitator or technical team. There is a distinct danger that the overall consultation process will be dominated by technical demands, and become fragmented around particular technical products. Stakeholders are then unable to achieve an understanding of the overall context within which their issues, and the various technical processes and products, fit. Building a shared context for water resource management is an important process in itself, often overlooked in a top-down approach. Finally, the involvement of stakeholders can both counteract and reinforce existing imbalances in power and capacity. Participation is in itself not sufficient to achieve equity and sustainability: this will depend on the nature of the participatory process that takes place.

***Keywords*:** *public participation; stakeholder consultation; Integrated Water Resource Management; Ecological Management Class; Ecological Reserve*

INTRODUCTION

South Africa's new water policy, in the form of the National Water Act (no.36 of 1998) introduces the requirement for proactive and participatory resource management, that is based on the principles of equity and sustainability. Under this policy, local stakeholders should be involved in setting "a joint vision" for their resource (DWAF, 1999 p. 4).

This 'desired state' that stakeholders[1] must agree on for a water resource is represented by the combination of 'Management Classes' and the associated 'Reserve' that is set to achieve this for a particular river system. The decision about a 'desired state' is multi-objective – it is required to meet social, economic and ecological goals. This decision is also distributive – the 'desired state' is essentially about the distribution, between different user sectors, interest groups and regions within a catchment, of the costs and benefits of using the resource in different ways. The selection of a 'desired state', Management Class and Reserve must therefore be based on values – there can be no single optimal or systematic solution.

This paper will focus on alternative approaches to making this decision. Though the Water Act demands public participation, it is not highly prescriptive of how this should take place. In particular, the new policy calls for considerable interaction between specialists and stakeholders: this is a very new experience for all concerned. This paper investigates the interaction of these technical and social aspects of a'desired state' process. What follows is not intended to be conclusive or even complete, or to provide a recipe for conducting a participatory process. It should instead rather be seen as a discussion of some of the ideas, insights and principles that have emerged from an exploration of this issue and the current context for it in South Africa. These ideas were developed through a variety of experiences: workshops held with stakeholders from the Inkomati Water Management Area, observation of the Department of Water Affairs and Forestry's (DWAF) participation processes in various catchments, and ongoing interaction with other researchers and practitioners in this field.

Participatory approaches: what are the options?

A variety of approaches may currently be adopted in conducting the required participatory processes. Discussion of these options will be structured as a contrast between the various elements of two hypothetical approaches (Table 1). This is presented as a dichotomy, but is intended to represent the ends of a spectrum. This spectrum moves from a distinctively 'top-down', specialist-centred or technocratic approach, to a more 'bottom-up', stakeholder or people-centred approach.

The first, and central, element separating these approaches is the role and importance of stakeholders in the overall decision-making process. In a chiefly specialist-centred approach it is likely that stakeholder involvement only begins after a technical team has reached a certain stage of progress in defining and debating the issues at stake. Participants then have the opportunity to select scenarios that the technical team has generated. Alternatively, stakeholders may be involved right from the start. This gives them the opportunity to contribute to framing and prioritising the issues for debate.

Participatory approaches may be oriented around 'products' or 'processes'. Product-oriented approaches tend to use highly structured, inflexible agendas, to ensure that the consultation process produces the contents required within the final report as quickly as possible. The relevance of stakeholders' issues and contributions is then determined by whoever sets the agenda. A more process-oriented approach employs open and flexible agendas, which can be used to surface participants' knowledge, perceptions, needs and values. In this way everyone is involved in building a shared context, including the social, economic and ecological issues at stake. The relevance of their contributions is therefore determined by the stakeholders themselves.

[1]The term 'stakeholders' as used throughout this paper is intended to imply 'resource users'. We recognise though that everyone involved, including government and specialists, has some stake in the outcome of resource management decisions.

Table 1: Contrasting approaches to participatory decision-making

'TOP-DOWN' **Specialist-centred**	**'BOTTOM-UP'** **Stakeholder-centred**
• Stakeholders only involved after technical team has reached a certain stage of progress. • Participants have opportunity to select scenarios.	• Stakeholders involved throughout the entire process. • Participants have opportunity to generate scenarios.
Product-oriented • Highly structured agenda, designed to meet bureaucratic stipulations.	**Process-oriented** • Open agenda, used to surface stakeholders' knowledge, perceptions, needs and values.
Passive involvement • Participants have option to contribute.	**Active involvement** • Contribution required from all participants.
Focus on technical processes • Sectors consulted separately. • Minimal discussion. • Gauge individual preferences, e.g. using questionnaires, checklists.	**Focus on social processes** • Sectors consulted together. • Extensive, inclusive discussion. • Gauge group preferences, through, and after, discussion.
Focus on differences • Addressing current conflicts.	**Focus on commonalities** • Designing a shared future.

A participatory approach can focus on either technical, or social, processes. Where there is a technical focus, often sectors are consulted separately – there is minimal discussion, and what does take place is usually between the participants and the technical team. The facilitator or technical team then tries to gauge the preferences of each individual sector, i.e., to find out what each sector would like for themselves. Conversely, with a focus on social processes, sectors are consulted together, and there is extensive discussion. The facilitator or technical team can then gauge the preferences of the group, i.e., to find out what the group as a whole wants, now that they have heard and discussed each other's needs.

Finally, there is the option to either focus on differences, or commonalities. Discussions based on differences often get caught up in addressing current conflicts. Conversely, a focus on shared needs and values helps to look to the future.

Compromise and consensus: success or failure?

What are the likely outcomes of these two contrasting approaches? We would predict that a participatory approach that employs the set of elements presented as the 'top-down' extreme is destined to deliver a compromise. The 'bottom-up' alternative is more likely to deliver a consensus.

Compromise is often seen as a positive outcome of a negotiation process. We would however argue that a compromise is an unfavourable outcome and process, because it is designed to create an equal distribution of unhappiness about a decision. A compromise is a lose-lose outcome, reached by splitting the difference between people's conflicting demands (Susskind and Cruikshank, 1987). Reaching a compromise involves confrontational interaction between participants, who compete to get the midpoint closer to their aspirations. Any technical process involving 'averaging' is already in the realm of compromise negotiation. This is particularly problematic where no natural midpoint exists, as is often the case when comparing the qualitative or discrete elements of various resource management scenarios.

A consensus, however, is a creative solution that everyone is happy with, and that everyone has been involved in creating. Reaching consensus requires a thorough analysis and exploration of the issues and options involved. The process relies on people recognising their interdependence, and that the best or only way to make sure that they get what they want or need is to help others get what they need first (Susskind and Cruikshank, 1987).

Because everyone is involved in creating a consensus solution, a sense of ownership results, with a resulting willingness to cooperate in implementation. Conversely compromises often inspire disinvestment from the process and product of negotiation (Susskind and Cruikshank, 1987) - often some or all of the negotiating parties develop the perception that they have been asked to give up the most in a compromise agreement, and will then seek to undermine its implementation.

Because reaching a compromise involves confrontation, relationships between participants are usually impaired. Conversely, the cooperative nature of consensual processes builds and improves inter-sectoral relationships. Building relationships takes time, thus the efficiency of the consensual process may seem low in the short-term (Susskind and Cruikshank, 1987). However, these relationships form the foundation and sustainability of all future cooperation, resulting in a higher overall efficiency of the participatory management process. Compromises may be faster to work out than consensus solutions, but the conflict they create often lingers to sabotage future processes and decisions.

The likely outcomes of the two extreme approaches discussed can then be summarised as follows (Table 2):

Table 2: Likely outcomes of alternative approaches.

'TOP-DOWN' **Specialist-centred**	**'BOTTOM-UP'** **Stakeholder-centred**
• Compromise • Reached by confrontation.	• Consensus. • Reached by co-operation.
• Alienation – Disinvestment.	• Ownership – Buy-in
• Relationships impaired.	• Relationships improved.
• Short-term efficiency high. • Overall efficiency low.	• Short-term efficiency low. • Overall efficiency high.

Stakeholder perceptions and preferences: fixed or co-evolving?

Why are these outcomes likely? What assumptions and inherent processes are at work?

A central assumption running through the features we have grouped as the 'top-down' extreme is that people's preferences or demands, and their perceptions about issues, are fixed – they can't or shouldn't change in the process of decision-making. This is a premise founded in the principles of conventional economic valuation, and is based on a social decision-making rule commonly referred to as 'consumer sovereignty' (Costanza and Folke, 1997). Under this premise attempts to alter preferences are futile – and may even be considered undemocratic.

If preferences are fixed then a compromise solution is the only option, and the fastest and seemingly fairest way to reach this compromise is by a technical process, for example, some kind of 'decision support system' that uses questionnaire results, various weightings etc. to produce an average of what everybody wants. This approach is based on the assumption that it is possible for an objective technical process to produce an optimal, equitable solution that is then acceptable to all concerned.

An alternate assumption is that people's preferences and perceptions can, and do, change when they are exposed to the experiences and viewpoints of others. Where people have initially conflicting demands, reaching a true consensus is really only possible if participants' preferences are able to converge. Robert Costanza and Carl Folke (1997) refer to this process as the 'co-evolution of preferences'. This coevolution takes place by a process of shared value formation through public discussion. People change their demands out of a motivation not just to help others meet their needs, but because their perceptions and understanding of the issues has changed.

Another key process contributing to these contrasting outcomes is the direction of interaction and communication that takes place. Where there is a focus on technical processes, what happens most is that the stakeholders talk to the technical team, and vice versa. Relationships between stakeholders then become irrelevant. With a focus on social processes, however, the stakeholders spend most of their time talking to each other. Relationships are critical. They start to affect the demands that people make on each other.

Can we implement a 'bottom-up' approach?

From the above discussion it is clear that we would propose that a successful participatory process will be one that leans toward the 'bottom-up' end of the spectrum described. The question that remains, however, is whether it is possible for us to implement such a 'bottom-up' approach in water resource management in South Africa at this time. Is this approach workable within the current policy context for participatory processes?

Experiences of current implementation of participatory processes and decisions would suggest not - unless there is a change in perceptions about the role of public participation within the overall resource management process. There is currently a distinct danger of the participatory process becoming fragmented around the particular legal and technical products that the Water Act requires. As depicted in Figure 1, separate processes are currently taking place for each product for which participation must be shown to have taken place, for example, establishment of a Catchment Management Agency, the setting of the Reserve, and the development of a Catchment Management Strategy. The result of this on participating stakeholders appears to have been much confusion, participation fatigue, and, perhaps most seriously, a general perception that their contributions are only welcome where they fit into a highly specific agenda, set entirely by government, or the technical team. Participants then fail to develop an understanding of the overall resource management context within which these different statutory products, as well as their issues - their lives and livelihoods - and thus their interest in participating, fit.

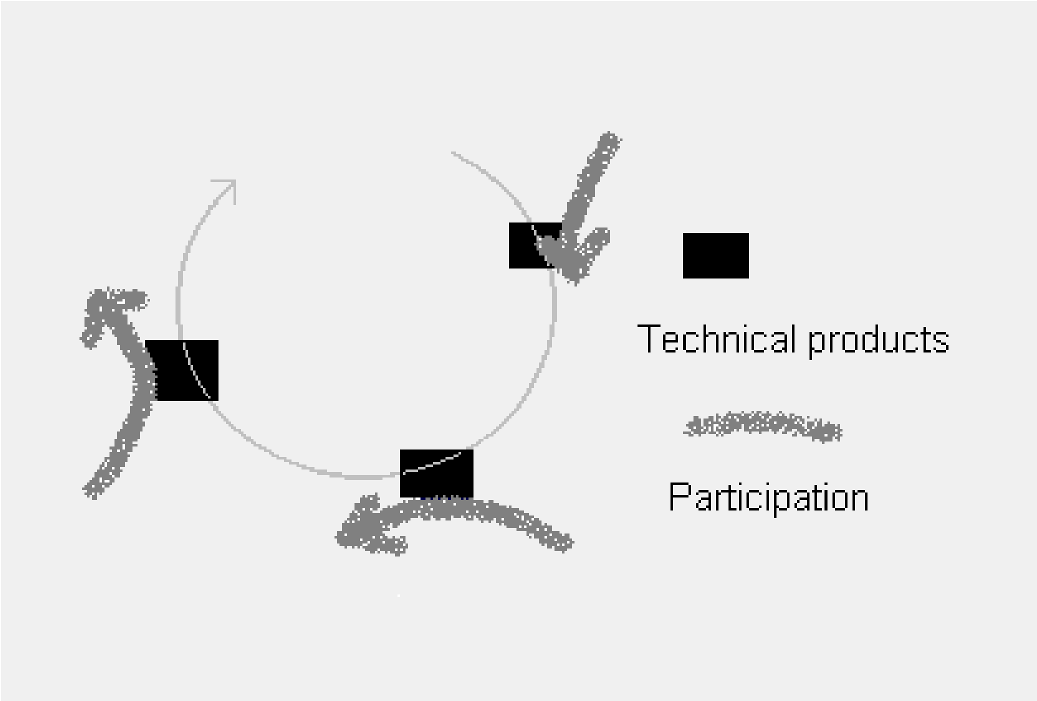

Figure 1: A fragmented participatory process

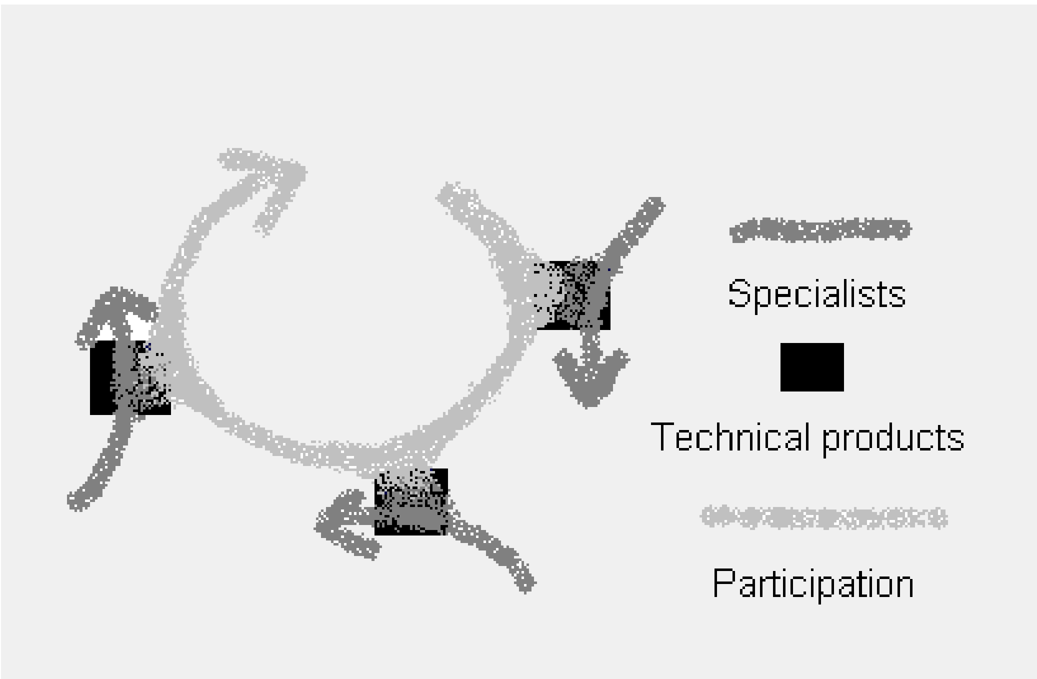

Figure 2: An integrative participatory process

Instead, we feel that the role of participation within the overall management process should rather be conceptualised as depicted in Figure 2. There needs to be a single, integrative participatory process, that creates continuity between stakeholders' exposure to various technical processes, and builds a shared understanding and knowledge of the overall context within which these processes, and stakeholders' issues, fit. This central integrative process, in addition to its involvement in developing the various statutory products with the help of the relevant specialists, also has an explicit purpose of its own. This ongoing participatory process must serve to build a genuine stakeholder management team, of people who are able to take responsibility for the effects that their actions have on the resource, and on each other. By contrast, in a fragmented approach there is a tendency for participation to be passive, and for stakeholders to defer all responsibility to government. Participants air their views, then sit back and wait for government to do something about their problems. It is unlikely that such an image of participatory resource management inspired our new national water policy.

Equity and sustainability?

The growing global trend toward more participatory management of natural resources reflects both ethical-democratic and pragmatic motivations for the involvement of public and stakeholders in both policy design and implementation (Webler and Renn, 1995). Potential democratic benefits of participation include the achievement of more informed, inclusive and equitable decision-making, particularly through the voice that participation can give to marginalised communities and sectors (Holmes and Scoones, 2000). More practical benefits include educating the public about resource or policy issues, generating 'buy-in' and thereby compliance or at least reduced resistance to implementation. Greater equity and sustainability of resource use and management is a potential positive outcome of all of these benefits.

However, these outcomes are not assured simply by involving stakeholders in some kind of consultation event. It is also very possible that the structure and process of participation actually enhances existing power imbalances between participants, resulting in decisions that perpetuate past inequities, and further marginalise the marginalised (Woodhouse and Hassan, 1999). Such power imbalances are particularly evident, for example, where participation takes place in a public meeting format, and only the most confident and articulate people are seen to contribute to the discussion.

A sense of ownership and subsequent 'buy-in' to participatory decisions is also not a given. It is just as likely that participants may perceive that, despite having actively contributed their views, needs and ideas, they have had little or no influence on the decision ultimately approved or implemented by government. Such perceptions of participation as 'tokenism' will probably create more opposition to policy implementation than if stakeholders had never been consulted at all.

We would however suggest that a 'bottom-up', people-centred approach - that emphasises social processes, builds relationships and strives for consensus through shared value formation and the co-evolution of perceptions and preferences – will be able to avoid these pitfalls of participation. South Africa's new water law cannot achieve equity and sustainability. Only people can.

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Application of pollutant reduction and weed utilization as management measures for aquatic weeds in the lower Kafue river, Zambia

Thomson SINKALA [1], Mick MWALA [2] and Enala MWASE [3]

[1] School of Mines-, [2] School of Agricultural Sciences -, [3] School of Veterinary Medicine -The University of Zambia, P. O. Box 32379 Lusaka Zambia

[1] tsinkala@mines.unza.zm

ABSTRACT

The aquatic weed situation in the Kafue River in Zambia continues to be a major challenge to the sustainable utilization of the water resources of the river. The general methods for managing the weeds, especially the water hyacinth, include use of bio-agents, chemicals, mechanical and physical approaches. These have had very little impact. Through this project, weed management strategies are being investigated which involve use of a Cleaner Production and Consumption (CP&C) approach and the utilization of the weed for economic purposes. In addition, the ecological implications of these methods are being assessed.

Results so far obtained show that all the 24 areas surveyed for CP&C have uncontrolled socio-economic activities which generate both point and non-point sources of pollution that enter the water bodies. To minimize pollution, efforts include devising policy and technical strategies with the involvement of the affected riparian community. Production of mushroom by the communities using the water hyacinth substrate has been demonstrated. Up to 2.1kg of mushroom was harvested from a single flush over a period of 4-5 weeks. The economics of the production are however, yet to be confirmed. If weed usage is proven economically and ecologically viable, the riverine community is envisaged to play a big role in aquatic weed management.

High numbers of invertebrates known to be sensitive to pollution have been recorded at several sampling sites in the weed-infested Kafue River implying that the water is of "good" quality for these aquatic invertebrates. The role of the water hyacinth as a sieve of pollutants may be playing a role here.

The implications of the removal of the weeds for economic use and the adoption of cleaner production and consumption strategies on the ecosystem will be reported at the end of the on-going project.

INTRODUCTION

In recent times the SADC Region has experienced increased adverse impacts imposed by aquatic weeds by way of disrupting industrial and socio – economic activities of the communities dependent on affected water bodies. In Zambia, the weeds in the Lower Kafue River are threatening important economic infrastructure such as the Kafue Road Bridge which accounts for 80 % of Zambia's international trade through the south, and the Kafue Gorge Dam responsible for 60 % of the country's hydropower requirements.

The significance of point sources of pollution along the Kafue river with respect to the proliferation of the water hyacinth in the river has long been recognized. Nakambala Sugar Plc which has about 13,413 hectares of land for the production of sugar and applies over 6,400 metric tons of fertilizers per year [Chabwela and Mumba, 1999], is considered to be the largest producer of nutrients to the river by virtue of its size [Environmental Council of Zambia, 2000], and Nakambala Sugar Plc also discharges into the river some waste products arising from the sugar processing factory. Nakambala Sugar Plc is being associated with the beginning of the water hyacinth infestation in the river in Mazabuka. Other point sources of pollution along the river, include the Nitrogen Chemicals of Zambia, a fertilizer production factory (though not in full operation for about three years now), Kafue Fisheries and Kafue Sewerage Treatment Plant. The tannery and yeast companies are in operation and discharge considerable amounts of effluents into the Kafue river at levels higher than the recommended standards by the Pollution Control Act of Zambia, in some parameters.

Cleaner Production concepts for the minimization of waste at source were officially introduced in 1997 to major stakeholders who included Governmental Officials, Industry Chief Executives, Academicians and Environmental Authorities when it was realized that industries needed to adopt cleaner methods of producing goods and services [Zulu, Sinkala and Mbewe, 2000]. Since then, there has been a series of training workshops on cleaner production in industry. The emphasis on all the training programs was placed on encouraging industry to identify simple housekeeping options, i.e. measures that do not require any real investment and thus have immediate pay-back periods. As a result, some options and projects identified as housekeeping have been implemented except those projects requiring investment, due to difficulties in Zambia to secure finances for projects. Zulu, Sinkala and Mbewe [2000], argue that the future of CP in Zambia depends on the issue of sustainability at both national and company levels. At the national level, the Government is expected to introduce incentives and other complementary policy guidelines that can facilitate adoption of CP in industry. The Environmental Council of Zambia has the special role to advise the Government on such matters. The Zambia Association of Chambers of Commerce and Industry (ZACCI) which is the institution hosting CP project in Zambia is of equal importance to influence national policy formulation favoring CP. At company level, CP in Zambia would be sustained with unquestionable top management commitment and the more industry realizes that prevention of pollution pays [Zulu, Sinkala and Mbewe, 2000].

Utilization of the weeds for economic purposes as a possible control strategy has been advocated for some time [National Academy of Science, 1976]. This approach requires involvement of local communities who live along the river and those that live on it; the riparian and fishing communities.

It is now a well known view that water hyacinth in the weed infested areas of the Kafue river is removing the nutrients including some toxic elements from the river, thus making the water quality better than it would have been in the absence of the weed. Caution must be made, therefore, that sources of nutrients should be dealt with first before advocating for total removal of the aquatic weeds from the river.

Since the water hyacinth weed is already established, eradication of the weed is practically impossible, and that conventional control methods such as chemical, physical and biological measures are by themselves not sustainable due to the nature of the affected part of the Kafue River.

In view of the above, this project targets weed control rather than eradication, as a management strategy. The approach taken is as follows:

(i) There should be efforts to promote the application of Cleaner Production and Consumption (CP&C) in human activities found in, for example, industry, municipalities and riverbank settlements, identified to be polluting the Kafue River system. As CP&C aims to reduce pollution at source, the weeds would be “starved” of nutrients and thereby reduce their proliferation.

(ii) Methods of weed utilization as experienced locally and elsewhere are to be examined, and those found appropriate are to be assessed and verified as an economic incentive by river bank communities contributing to weed reduction.

These two avenues are aimed at maintaining aquatic weeds at manageable levels while the weeds continue to act as pollutant filters in the river. The two weed control avenues are being monitored for their effect on the ecosystem, as a way of assessing their sustainability.

METHODOLOGY

Study site

This study is being carried out along the Kafue River between Mazabuka town and Shingoma village before the Kafue Hydroelectric dam down the river in Lusaka Province. The area follows a 70km stretch of the river (Figure 1). It is within this area that the weed has had negative impacts on various activities requiring the use of the river resources.

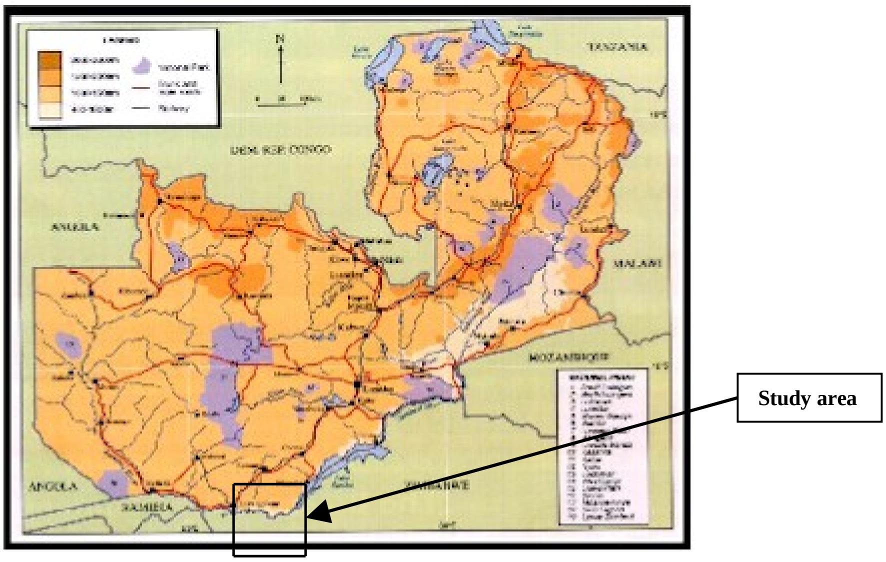

Figure 1: Map of Zambia showing area of study along the Kafue River

Identification of Pollution Sources

Water quality: Eleven (11) sampling sites along the river are sampled for water quality. Eight of these sites receive effluents from farming areas and factories. Water sampling is being done at least once in each of the three main climatic seasons of Zambia, i.e. hot-wet season (November-April), cool-dry season (May-August) and hot-dry season (September-October). Water samples are taken to the National Institute for Scientific and Industrial Research in Lusaka for analysis. Parameters being measured include pH, conductivity, turbidity, alkalinity, hardness, chloride, sulphate, nitrate, ortho-phosphate, suspended solids, total solids, sodium, potassium, magnesium, calcium, iron, manganese, zinc, lead, copper, cobalt, nickel and cadmium.

Soil quality: Nine (9) strategically selected sites were sampled for soil analysis. The samples were tested by the Department of Soil Science, School of Agricultural Sciences at the University of Zambia.

The following parameters were analyzed: pH, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, chlorine, iron, lead, cobalt and cadmium.

Socio-economic activities: A questionnaire was distributed to 100 persons living in the riverine area to investigate their socio-economic activities that would be contributing to non-point sources of pollution to the river system. These were complemented by interviews and observations. Areas emphasized included cultivation, livestock rearing, tree cutting and waste management.

Utilization of Aquatic Weeds for Socio-economic Benefit of Riverine Communities

Mushroom cultivation: Training in mushroom cultivation was carried out successfully in five riverine communities; Kansenje, Kasaka A, Nutrition group, Kasaka B and Chikupi. The total number of people involved in this training was 59.

Vegetable gardening: Communities at Kasaka A, Kasaka B and the Nutrition group have voluntarily established fields for vegetable growing using the water hyacinth as fertilizer. The yields will be compared to those from fields utilizing commercial fertilizers.

Implication of Weed Removal on Aquatic Ecosystem

Water quality of the river: For this purpose, three strategically selected points on the river are being sampled for water quality in the same way as explained for the effluents above.

Aquatic invertebrates: Aquatic invertebrates are sampled at the same sites and time period as for the water quality. The organisms are sampled using a dip and scoop equipment. These are sorted out from debris and preserved in 70% ethanol for identification in the laboratory.

RESULTS

Pollution Sources

Quality of effluents: The summary of ranges of some water quality parameters obtained so far in comparison to the standards for effluent quality set under Zambia's Statutory Instrument No. 72 of 1993; the Water Pollution Control (Effluent and Waste Water) Regulations, are shown in Table 1. Suspended solids, phosphates and nitrate in the effluents coming from point sources of pollution were at times found to be over the limit set by the Act.

Soil quality: The levels of nutrients found in the soils along the Kafue river are shown in Table 2. All the soils tested contained sufficient quantities of all the plant nutrients required to support most natural vegetation (N,P,K,Ca, Mg, Cl and Fe). The levels of the potentially toxic elements Cd, Pb and Co were low.

Socio-economic factors: Socio-economic activities identified among the riverine communities of the Kafue river included fishing, gardening, tree cutting, vegetation burning, livestock rearing and sand mining. Most of the settlements were also observed to be located too close to river/stream banks, and used free-range ablution. Pollutants generated by these factors include fertilizers and pesticides applied in farms, animal and human faecal matter, waste dumps, ash, organic waste matter, soil/sediment lost via water and exposed natural rock. Table 3 shows the summary of the survey.

Utilization of Aquatic Weeds

Mushroom cultivation: The communities participating in mushroom growing were able to harvest the mushrooms with varying yields due to differing management commitments. At one site, a total of 3.2 kg of mushrooms was harvested over a period of about 40 days from 20x2kg moulds of water hyacinth substrate. This result entails a biological efficiency of 8%, which compares well with what has been reported as an average of 10% from various substrates. Selling of mushrooms, in this case the oyster type of mushroom would fetch K8,000.00 (US$2.2) per kilogram at whole sale price.

Results on vegetable gardening using water hyacinth as manure are being awaited.

Implication of Weed Removal on Aquatic Ecosystem

Water quality of the river: Three sites on the river were sampled for the water quality analysis. Summary results are shown in Table 4. In general, the water in Kafue river is of acceptable standards in comparison to that expected in normal fresh waters. The phosphates and calcium were, however, found to be higher than the recommended levels for fresh waters. Of concern is the higher levels of zinc, lead and copper.

Aquatic invertebrates in the river: So far, 13 orders of aquatic invertebrates have been sampled. The organisms include the mayfly larvae, stonefly nymph and caddisfly larvae.
Several genera of snails including those of the genera *Lymnaea, Biomphilaria, Bulinus* which are important in the transmission of disease pathogens to humans and animals were collected from the river, particularly from the weed infested areas.

Table 1: Summary of quality of effluents in comparison to Water Pollution Control Regulation standards

PARAMETER	**REGULATION**	**SITE NUMBER**							
		1	**3**	**4**	**5**	**11**	**12**	**13**	**14**
pH	6.0 - 9.0	Within	Within	Within	Within	Within	Within	Within	Within
Conductivity	4,300 µS/cm	Below	Below	Below	Below	Below	Below	Below	Below
Turbidity NTU	-								
Total alkalinity mg/L	-								
Total hardness mg/L	-								
Chloride mg/L	-								
Sulphates mg/L	1500 mg/L	Below	Below	Below	Below	Below	Below	Below	Below
Nitrate N µg/L	5 µg/L	**Above**	Below	Below	**Low to high**	**Low to high**	**Above**	**Above**	**Above**
Total ortho-Phosphate mg/L	1.0 mg/L	Below	**Low to high**	**Low to high**	**Low to high**	**Low to high**	Below	Below	**Above**
Total suspended solids mg/L	100 mg/L	Below	Below	Below	**Low to high**	**Low to high**	Below	Below	Below
Total dissolved solids mg/L	3,000 mg/L	**Low to high**	Below	Below	Below	**Low to high**	Below	Below	Below
Total solids mg/L	-								
Sodium mg/L	-								
Potassium mg/L	-								
Magnesium mg/L	-								
Calcium mg/L	-								
Iron mg/L	2.0 mg/L	Below	Below	Below	Below	Below	Below	Below	Below
Manganese mg/L	1.0 mg/L	Below	Below	Below	Below	Below	Below	Below	Below
Zinc mg/L	-								
Lead mg/L	-								
Copper mg/L	1.5 mg/L	Below	Below	Below	Below	Below	Below	Below	Below
Cobalt mg/L	1.0 mg/L	Below	Below	Below	Below	Below	Below	Below	Below

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Table 2. Soil analysis

Sn	Sample identity	pH $CaCl_2$	N (%)	S (%)	Cl- (%)	P (mg/kg)	K (me/100g)	Ca me/100g)	Mg me/100g)	Fe (mg/kg)	Pb (mg/kg)	Co (mg/kg)	Cd (mg/kg)
1	Chanyanya Fish Camp	6.52	0.06	0.20	0.18	0.60	0.78	32.75	18.58	7.20	0.40	0.54	0.006
2	Kaleya bridge	6.16	0.15	0.17	0.13	3.64	1.28	17.60	12.08	12.80	0.68	0.22	0.006
3	Musikili bridge	6.17	0.17	0.30	0.13	8.65	2.87	21.65	15.50	9.00	0.68	0.28	Trace
4	Nakambala ND 2	7.76	0.20	0.23	0.18	4.80	1.98	40.35	24.25	3.80	0.58	0.22	0.008
5	Ceres farm-Mazabuka	6.73	0.08	0.37	0.04	21.11	1.89	15.00	4.58	2.40	0.64	0.32	0.006
6	Neganega stream	6.42	0.08	0.22	0.13	7.49	1.35	9.35	3.67	5.20	0.54	0.28	Trace
7	Nansenga stream	5.52	0.09	0.31	0.09	17.05	1.04	11.35	5.67	17.60	0.30	0.36	Trace
8	Shingoma village	5.21	0.06	0.18	0.04	9.56	0.46	6.40	4.67	21.00	0.58	0.42	Trace
9	NCZ sampling point 12	4.11	0.06	0.29	0.04	67.76	1.10	3.45	1.58	31.40	0.18	1.46	Trace

Key
'Trace' = Zero
mg/kg = milligrams of element per kg of soil
me/100g = milli-equivalents of element per 100g soil

Table 3. Socio-economic factors leading to generation of pollutants/nutrients from diffuse sources (based on questionnaire and observations)

S/no.	FACTORS	PERCENTAGE (%)
1	Cultivating on river/stream bank	75.00
2	Free range livestock	87.50
3	Riverbank erosion	70.83
4	Riverbank exposure	58.33
5	Absence of vegetative cover in surrounding	58.33
6	Free-range ablution	87.50
7	Livestock kraal on/near river/stream bank	66.67
8	Settlements on edge of river/stream	70.83
9	Quarrying/brick-making in/along river/stream bank	33.33
10	Late burning	41.67
11	Prominent animal tracks	54.17
12	Uncontrolled waste dumping	66.67
13	Absence of planned management of vegetation cover	75.00

Table 4. Water quality of Kafue river in comparison with recommended quality levels in fresh water.

PARAMETER	NATURAL LEVELS IN FRESH WATER	SITE NUMBER		
		10	**15**	**19**
pH	6.8-8.5	Within	Within	Within
Conductivity	10-1000	Within	Within	Within
Turbidity NTU	1-1000	Within	Within	Within
Total alkalinity mg/L	-	Within	Within	Within
Total hardness mg/L	<500	Within	Within	Within
Chloride mg/L	<2	Within	Within	Within
Sulphates mg/L	2-80	Within	Within	Within
Nitrate N μg/L	5	Within	Within	Within
Total ortho-Phosphate mg/L	0.005-0.02	**Above**	**Above**	**Above**
Total suspended solids mg/L	1,700	Within	Within	Within
Total dissolved solids mg/L	-	Within	Within	Within
Total solids mg/L	-	Within	Within	Within
Sodium mg/L	$<1-10^5$	Within	Within	Within
Potassium mg/L	<10	Within	Within	Within
Magnesium mg/L	1-100	Within	Within	Within
Calcium mg/L	<15	**Above**	**Above**	**Above**

Continued

Table 4. Water quality of Kafue river in comparison with recommended quality levels in fresh water.

Iron mg/L	-	Within	Within	Within
Manganese mg/L	-	Within	Within	Within
Zinc mg/L	0.000001-0.0001	**Above**	**Above**	**Above**
Lead mg/L	0.000001-0.0001	**Above**	Within	Within
Copper mg/L	0.000001-0.0001	**Above**	Within	Within
Cobalt mg/L	-	Within	Within	Within
Nickel mg/L	0.000001-0.0001	Within	Within	Within
Cadmium mg/L	0.000001-0.0001	Within	Within	Within

Key

(-) = Not available

DISCUSSION AND CONCLUSIONS

All major point sources of pollution emitted nitrates and phosphates, the main nutrients for the water hyacinth, at higher levels than recommended.

Control of pollution from point sources such as the factories and larger plantations as the Nakambala Sugar Plc through the use of Cleaner Production and Consumption techniques to minimize the movement of pollutants to the water resources is possible so long as the authorities involved are committed. Techniques to reduce pollutants to the river include the adoption of effluent recycling, particularly from agricultural plantations which lose as much as 50% of the fertilizers applied in the fields to the river. This method is already being applied to some level by the Nakambala Sugar Plc. The sewerage treatment ponds should also ensure that their effluents are efficiently treated to remove nutrients, especially phosphates before being discharged to the river. Fishponds, settling and oxidation ponds, lagoons where slurry is discharged must be lined with impermeable material in order to contain nutrients within the ponds and lagoons or limit the infiltration into ground water [Environmental Council of Zambia, 2000].

Whereas emphasis of CP principles is largely placed on point sources of pollution, CP principles on non-point sources appear to be an emerging aspect. Very little information exists on consumption patterns. As evidenced from the results so far obtained in this study, non-point sources of pollution might not be receiving the attention they deserve. River bank activities such as livestock rearing, gardening, settlements, free –range ablution, de-forestation and vegetation burning may be major sources of nutrients for the water hyacinth proliferation in the river. Although pollution from non-point sources is difficult to quantify, it nevertheless calls for the need to identify strategies that would help minimize the pollution from these sources. One inevitable strategy is to institute and implement policies that would ensure the control of socio-economic practices near water bodies. The strategy here includes recommending reviews, consolidation, updating and enforcement of existing Zambian laws through agencies of the Government of Zambia. In addition, innovative and alternative policy initiatives to enhance management of riparian environments in the country should be explored.

The observations in this study also indicate that once the various ways of utilizing the weed are seen as a source of income, more weeds will be harvested for their use. The individuals and communities participating in this study in mushroom growing are enthusiastic about it and it is hopeful that more people will participate in this kind of livelihood thereby bringing the weed coverage to acceptable levels in the river.

The current quality of the water can be seen through some of the organisms that the river is able to support, such as the mayfly larvae, stonefly nymph and caddisfly larvae which are known to be highly sensitive to pollution. The habitable water quality may be due to the nutrient-filtering ability by the water hyacinth.

ACKNOWLEDGEMENTS

The cooperation received from the Kafue riverine communities to this study is highly appreciated. Thanks to the Water Research Fund for Southern Africa for funding the project in Zambia.

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Liberal peace and the price of (human) security: The new water architecture in Zimbabwe

Larry A. SWATUK

School of Government, University of Western Cape, Private Bag X17, Bellville, 7535

swatukinthebushes@yahoo.com

ABSTRACT

Water reform processes are underway throughout the SADC region. From regional protocols and projects to national institutional and sectoral restructuring, these activities are said to enhance peace and security and to promote development in the region. In this paper, I use the current water reforms in Zimbabwe as a vehicle through which to interrogate these assumptions. Does the creation of a new water architecture enhance prospects for peace and development in Zimbabwe? My argument is that while many aspects of the water reform process are necessary, even laudable, they will ultimately fail if subjected to the same market logic which is forcing a 'race to the bottom' in the region.

1. WATER REFORM

> I have seen sovereign states and ethnic groups within nations go to war over every resource – oil, land, humans, diamonds, gas, livestock, or gold – but never, interestingly, over *renewable resources*, and never, in particular, over water development and dams. True, water has never been more scarce, and there is always a first time for anything. But there is also a difference between reaching a snapping point, and snapping; between being pushed to the brink of conflict over water and waging a water war … With all due respect to my friends, have battles been fought over water? Is water scarcity a *casus belli*? Does it in fact divide nations? My own answer is no, no and no.
>
> ■ Asmal (2000)

> Less attention should be given to researching the links between environment and *violent conflict*, and more be devoted to obtaining a better understanding of how environmental change is related to *human security*.
>
> ■ Lonergan (2001)

Water reforms are underway in Zimbabwe. A new water act was promulgated in 1998, replacing the old act of 1976. Of significance is the fact that, under this new act, all water in Zimbabwe is the property of the state. Everyone has a right to a basic amount of clean water for which no permit is required (Nhidza, 2001: 13). Beyond basic consumption, users will be required to obtain 'permits'. Permits will be issued by the 'lowest appropriate authority'. Thus, the fact as well as the idea of 'private water', of 'rights' granted in perpetuity, is no more. At the same time that ownership is being 'centralised', management decisions are being decentralised to identified 'stakeholders'. To facilitate this decentralisation of authority, a new water architecture has been constructed. A parastatal, the Zimbabwe National Water Authority (ZINWA) has been created to oversee the development and use of all water in the country. They are to be advised by the Department of Water Development (DWD). The country has been divided into seven catchments and water resources are to be managed along catchment lines. To this end, Catchment Councils, Sub-catchment Councils and Water User Boards have been created to facilitate the efficient, equitable and sustainable management of water in the country. Here, the subsidiarity principle applies – for efficient, equitable and sustainable development to occur, water must be managed at the 'lowest appropriate level'. Central to this thinking is the notion that stakeholders must meaningfully participate in the system for the system itself to work. Where these waters involve shared international river systems, a series of Water Commissions have been or are being established.

2. SECURITY AND DEVELOPMENT

Underpinning this entire exercise are the merging discourses of 'security' and 'development'. Perhaps best illustrating such a merger in regional thinking is the 1995 SADC Protocol on Shared Watercourses: water resources must be developed but they must be developed in such a way that gains for one do not result in losses for another. More specifically,

> Member states shall utilise a shared watercourse system in an equitable manner. In particular, a shared watercourse system shall be used and developed by member states with a view to attaining optimum utilisation thereof and obtaining benefits therefrom consistent with adequate protection of the watercourse system … Shared watercourse systems and related installations, facilities and other works shall be used exclusively for peaceful purposes … (SARDC et al, 1995: 163).

Moreover, water use is set within the wider framework of natural resources management. 'Article 5 of the Treaty establishing SADC says one of the Community's major objectives is to "achieve sustainable utilisation of natural resources and effective protection of the environment"' (SARDC et al, 1995: 151).

National water reform exercises are being undertaken throughout the SADC region. These activities are meant to complement cooperative regional initiatives. In the case of Zimbabwe, several sources of 'insecurity' have been acknowledged as motivating factors for reform: (i) Zimbabwe is a landlocked country generally poor in water resources endowment; (ii) the country is prone to regular periods of drought; (iii) some parts of the country are also prone to extremely heavy rainfall; (iv) increasing population growth combined with the growth of urban and peri-urban centres puts pressure both on the resource and systems of delivery; (v) changing and expanding structures of production heighten demand and create competition for water; (vi) access to water is highly inequitable; and (vii) extant institutional arrangements are cumbersome, corrupt, and uncoordinated (WRMS, 2000). Taken together, *national* water security is said to be threatened.

3. 'SECURING' WATER: LOGICS AND LANGUAGES

National water reforms do not occur in a vacuum. Indeed, one could argue that were it not for a wide variety of especially global factors -- 'water insecurity' or not -- no reforms would have taken place at all. It is imperative that we upack the various logics and languages at work in the water reform exercise. To simply assume coherence on the part of a wide variety of actors, forces and factors is to court outright failure of the process – if by 'success' we mean achieving stated aims *as they are stated*, and not seeing them deployed as code-words on behalf of extant, entrenched interests.

The various logics and languages at play toward the realisation of water reforms for peace and development may be spatially disaggregated – global, national, sub-national and sectoral. These may be further broken down in myriad ways. Given limitations of space, I will only focus on global and national factors. Also, there is a time dimension to these logics and languages. Some have a long pedigree; others are of more recent vintage; others influential in the past have been displaced by more powerful contemporary narratives.

2.1 Global

Global environmental, political and economic interests are at play in the Southern African region. The most influential – and potentially most destructive, in my estimation – of these forces is that group[1] mobilised around what Duffield calls 'liberal peace':

> The idea of *liberal peace* … combines and conflates 'liberal' (as in contemporary liberal economic and political tenets) with 'peace' (the present policy predilection towards conflict resolution and societal reconstruction). It reflects the existing consensus that conflict in the South is best approached through a number of connected, ameliorative, harmonising and, especially, transformational measures (2001: 10-11).

How these ideas translate into policy is most readily seen in the present directions being taken by donors in the SADC region. All major donor policies rely on (at least) the following five assumptions: (i) state-by-state structural adjustment programmes are a necessary part of regional economic growth and development; (ii) regionally integrative activities – e.g. in the areas of trade and transboundary natural resources management – build economies of scale and facilitate regional comparative advantage so facilitating sustainable niche development; (iii) wherever possible, 'developmental' activities should cultivate 'smart-partnerships' between civil society actors in recipient countries and private enterprises in donor countries; (iv) recipient states should become facilitators rather than initiators of development. Hence, they should concentrate on creating and upholding regulatory frameworks wherein the private sector can pursue developmental activities which are self-defined; and (v) all of these activities should be undertaken in the spirit of democratic participation, including transparent and accountable forms of decision-making.

In terms of Zimbabwe's water reforms, these 'liberal peace' assumptions underpin the activities of, in particular, the catchment donors -- e.g. GTZ, DFID, SIDA – who have carved up Zimbabwe in a tangible demonstration not of a 'new imperialism' but of 'liberal power' (Duffield, 2001: 34). For example, with regard to the Save Catchment, the new water architecture, supported by a generous donation from SIDA, purports to (i) devolve power to stakeholders who will manage the system on a user-pay, polluter-pay, sliding-water price, commercial basis; (ii) manage the resource in an environmentally integrative way – on the basis of 'catchments', rather than political boundaries; (iii) include local NGOs, consultants, companies and the like working in league with their counterparts from Sweden and/or other Western countries (e.g. to monitor environmental health; to manage water points; to build dams); (iv) limit central state involvement through the creation of a parastatal, ZINWA, and devolve real power to stakeholders through Catchment Councils, Sub-catchment Councils, among other things; and (v) to democratise the entire process through regular elections to Council, inclusive membership criteria, etcetera.

Stated goals of 'equity, sustainability, and participation' appear in virtually every policy document. Donors themselves rely on expert knowledge – e.g. water and civil engineers, environmental biologists – and a constructed, self-referential 'epistemic community' – e.g. UNEP, GEF, the World Bank -- that increasingly counsels market 'solutions' to abiding problems of resource scarcity and inequitable access. Donors are in a very powerful position because they have knowledge and capital. Moreover, theirs is a coherent approach to peace and development in Southern Africa. It is not confined to a particular sector – e.g. water – rather, donor approaches to water resource management are part of a logical framework which hitches liberal political and economic processes to peace-keeping, -making, and -building operations throughout the so-called 'South'. To quote from a background document to a recent EU-SADC conference: 'The main thrust of the management of

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[1] According to Duffield (2001: 12), 'liberal peace is embodied in a number of flows and nodes of authority within liberal governance that bring together different *strategic complexes* of state-non-state, military-civilian and public-private actors in pursuit of its aims.

shared river basins is to find ways of turning potential conflicts into constructive cooperation, and to turn what is often perceived as a zero-sum predicament … into a win-win predicament' (NEDA, 1997: i).

Alongside the 'liberal peace', are equally compelling global logics and languages of sustainable development, human security, and environmental security. An endless array of extra-regional actors are motivated by such concerns. Increasingly, however, their activities are filtered through the rather myopic lenses of the liberal peace. What is so problematic about this? It may be asked. To me there are three problems of fundamental importance related to discourses and practices of 'liberal peace'. First, an unexamined and increasingly uncontested belief in the promise of 'the market'. Second, an uncritical, unreflective and too often self-righteous propensity to 'experiment' on peoples of the 'South'. Third, a continuing failure to root itself, to make itself truly 'in and of the South', the language of 'participation' notwithstanding. Let me address each of these points in turn.

3.1.1 Belief in the Market

Under liberalism, everything must be given a monetary value. To sustainably 'manage' a resource, it must first be enclosed, possessed, valued. Consider the following statement: '[W]ater … is fugitive. To put water to use, it must first be captured ("reduced to possession"). This requires investments in storage facilities, pumping equipment and conveyance infrastructure… The use of water for irrigation, then, draws the various users into a web of relationships in relation to the infrastructure; fellow users, and outside agencies, such as financiers' (Bolding et al, 1999: 227-8). In this framing, water is neither a fact nor a fact of life; it is, instead, a factor of production. To conceive of water in this way is to allow the language of the liberal peace to slip in almost unnoticed. People need water; water is a scarce commodity; the true value of water must therefore be paid or else it will be 'wasted' and supply will run short.

Clearly, storage facilities and delivery systems must be built and maintained. To do this costs money. However, it is a mistake to consider the management of water as a closed circuit, as a self-financing 'sector'. Water is a fundamentally central component to human security. It is integral to all aspects of human security as defined by the UNDP. Following from Lonergan above, it is time to begin thinking of access to water, not as a traditional security issue, but as the essential element of human security; not as an 'economic good' but as basic human right (Gleick, 2000). The UNDP in 1994 highlighted seven components of 'human security':

- Economic security (e.g. assured basic income)
- Food security (physical and economic access to food)
- Health
- Environmental security (e.g. clean water, air and non-degraded land)
- Personal security (e.g. freedom from physical violence and threats)
- Community security (e.g. freedom from 'ethnic cleansing')
- Political security (protection of basic human rights and freedoms)

Access to water is a central component of each of these seven items. Water is needed to run economies, to grow food, to ensure good health and a stable natural environment. Denying an individual or a community access to water jeopardises both personal and community security and calls into question the protection of basic human rights and freedoms. Without access to water, human security can not be realised. User-pay schemes, or delivery systems based first on a community's 'willingness to pay' fail to understand the way water is integrated into the social fabric.

The liberal peace perceives underdevelopment as a 'threat' to 'security'. It also perceives the market to be the solution. Consider the following two statements taken from a SIDA document: First, with regard to 'environmental security and water management', 'According to Ohlsson, the potentially greatest future cause of conflicts in the SADC region is water scarcity. Competition over natural resources may lead to serious conflicts. Hence, means to eliminate or diminish these are important to find…' (1997: 11). Second, with regard to 'water management': 'As the realisation increases that fresh water of satisfactory quality is a scarce and limited resource, matters related to management of the water resources have become more into focus [sic]… At least four conditions need to be fulfilled to carry through efficient water allocation: (1) well defined user rights, (2) pricing at its marginal cost, (3) information related to availability, value, quality, delivery times, and (4) flexibility in allocation responding to technologic, economic and institutional changes (1997: 12, 13). The leap in logic that takes us from potential violent conflict (undemonstrated) to user-pay fees as a solution is nothing short of astounding. Yet, it is this very logic that undergirds water reforms not only in Zimbabwe, but throughout the SADC region (DFID, 1998; GTZ, 2000; WRMS, 2000; see also Bond, 2001 for the South African case).

While water management forms one component part of a comprehensive and coherent Northern 'new security regime' (Duffield, 2001: 16), this same reform process argues that water can be successfully managed apart from other resources. This management must treat water as an economic good and, ultimately, must be self-financing; hence, 'user-pay' fees, permit application fees, levies and the like. In the words of Patrick Bond, this is a recipe for 'residual water apartheid' based not necessarily on race, but clearly on class (2001).

3.1.2 A Grand Experiment

The second problem with the 'liberal peace' perspective is its propensity to experiment on peoples of the South. In this it is unapologetic: 'since the inception of development discourse at the end of the Second World War, development has always had as its aim the modernisation and transformation of the societies that it encounters' (Duffield, 2001: 39). According to Duffield (2001: 42), development under 'liberal peace'

> is better described as an attempt, preferably through cooperative partnership arrangements, to change whole societies and the behaviour and attitudes of the people within them. In attempting to promote direct social change, development has increasingly come to resemble a series of projects and strategies to change indigenous values and modes of organisation and replace them with liberal ones. Ideas of empowerment and sustainability are largely refracted through a lens of behavioural and attitudinal change… [T]his process is synonymous with a change from traditional to modern values.

In terms of Zimbabwe's water reforms, this perspective is particularly fraught. Under the pretense of 'participation', the interests of rural communities are said to be represented through their chiefs on sub-Catchment and Catchment Councils. The dynamics of these meetings demonstrate the power of white farmers and Western ways of 'knowing'. The 'modern' settings themselves can be said to undervalue if not delegitimise traditional knowledge structures and modes of communication. Women, the traditional managers of water resources in Africa, are nowhere to be found on these formal councils. As Councils comprise commercial stakeholders, they tend to represent and defend the interests of those groups already fully integrated into capitalist market economies.

In Sibanda's view (2000: 37-8), '[f]or the donors, IGOs and NGOs, community participation means that the local people accept the programmes that are designed by outsiders. They will dig trenches and wells for water projects, they will make bricks, provide stones and water for construction projects. Community participation often means providing free and value free labour and materials. Very rarely does participation involve decision-making, planning, intellectual inputs and creative thinking, nor provide solutions to problems'.

In terms of the water reform process, Sithole reports similar perceptions by 'participants' at several meetings during the run up to the formation of the Mazowe Catchment Council. For example, at a Nyagui sub-Catchment Council meeting (06-10-99), one participant remarked: 'We may say we are changing the system, yet we are bringing it back in another way, this is cosmetic change, now we say those with dams must be given surplus water, what has changed then, where is the change?' (Sithole, 2000: 9). For water reforms to be sustainable, Latham argues, the 'world-views' of local people must be respected, not trivialised (Latham, 2000: 2). Sibanda argues similarly that natural resources management must be located in the 'cosmovision' of local peoples:

> In Tonga culture for example, life is celebrated through the utilisation of natural resources. Therefore, resources are conserved because the Tonga understand them to be prerequisitesto the celebration of life today as well as tomorrow. The continued availability of natural resources guarantee the continuation and celebration of life. In the Tonga cosmovision, there is no conservation without utilisation and no utilisation without responsibility (Sibanda, 2000: 40).

By definition, liberal reforms cannot value traditional understandings of and relations to the natural world. Common property regimes, for example, are anathema to liberal conceptions of individual freehold tenure. Totems and stories as regulators of resource use find no place in 'the rule of law'. As liberal peace rests on liberal 'order', traditional ways of managing resources can, at best, only be co-opted to suit the needs of the 'new public administration'. Recent difficulties between state officials and communal peoples in Kairezi, bordering on Rhodes-Nyanga National Park, may be indicative of coming struggles over water resources.

Without going into details at this point, the history of Kairezi (the local spelling for what was known as Gaeresi Ranch) is one of land alienation: first by Cecil Rhodes, second by a commercial syndicate which, in 1963, purchased the 63,000 ha Inyanga Block from the BSAC, and lastly from the Zimbabwean state which created the national park out of much of this land. During the colonial period, the Tangwena resisted relocation. Resistance included 'internationally publicised court cases and on the land' where Chief Rekayi Tangwena and his followers argued 'that their ancestral rights preempted the alienation of commercial land in the area' (Moore, 1993: 385). Following 'liberation' they were 'resettled' on a fraction of this land. In the late-1980s, the national park was to be expanded into their resettlement area. The following exchange, described by Moore (1993: 390), at a 1991 meeting to consider the 'new border' is instructive:

> [T]he local chief provoked applause from his constituents when he invoked the memory of forced evictions from the same lands in the 1970s: "The National Park wants to burn huts in my area. We thought the whites had returned." The MP responded by stressing … the government recognises property boundaries as they are written in title deeds and demarcated with beacons placed by a state official from the office of the surveyor general, not as they are remembered in oral traditions. The chief responded by again appealing to his ancestral claims to "rule the land", and began to describe his "traditional" boundaries … The MP chastised chief and followers alike: "You don't know your boundary. Without boundaries there would be only war." Invoking the colonial separation of functionally discrete cordoned spaces sanctioned by property deeds, the MP scolded his constituents for not having a map to reveal the "true boundary".

The language used and logics invoked by the MP reflects that of the now dominant 'liberal peace' – without private ownership, without taxation and user-pay fees there 'would be only war'. In this way, 'tradition' is seen to be destabilising. The best that the liberal peace can do, is help local peoples participate in their own transformation. In Duffield's words (2001: 34), 'Lberal peace aspires to secure stability within the political complexes that it encounters on its shifting borders through the developmental principles of partnership, participation and self-management. People in the South are no longer ordered what to do – they are expected to do it *willingly* themselves'. Most willing, it seems, are those both with the most to lose and potentially the most to gain – i.e. those already politically and economically empowered within the Zimbabwean state form. I return to this point below.

3.1.3 In Search of Local Roots

The third and final problem with the 'liberal peace' that I wish to discuss is the way it fails to root itself in the local imagination. A great deal of what passes for politics in Southern Africa today reflects external agenda. Ideas conceived in the West and deemed 'good' are simply exported to the region as a matter of donor policy – for example, peace parks, community based management of natural resources, transboundary management of shared river basins are considered both uncontroversial and non-political. It is as if invoking the language of 'peace', 'community' and 'sharing' is sufficient to buy local favour.

In terms of the new water architecture, it is clear that donors have convinced themselves and many others that the exercise itself is beyond reproach. 'Stakeholders' are to be involved. 'Participation' is to be encouraged. Management will be at the level of the 'lowest appropriate authority'. 'Equity' will be the overall aim, while management will be 'efficient' and 'sustainable'. In the WRMS team's own words (2000: 8), 'the wider objective of the WRMS project was to achieve "sustainable, equitable and economically feasible development in Zimbabwe through the proper use of water resources whilst taking into account the shared international watercourse systems"'. Moreover, the 'project was designed "to engender a stakeholder focused initiative so as to achieve a consensus strategy"' (2000: 8).

I am not suggesting that these ideas are not important. What I am suggesting is that they must be more self-consciously considered. Take 'peace parks' for instance. These forms of transboundary natural resource management have been heralded both in the West and in state houses throughout the region as 'bold initiatives' (Cape Times, 7/10/01; also, De Villiers, 1999). However, a recent SARIPS study suggests that they are in fact indicative of 'new forms of land alienation' (Moyo & Tevera, 2000: 10). And a recent IUCN study suggests that TBNRM provides opportunities for 'natural resource raiders' to operate under the guise of 'partnerships' and 'joint ventures' (Katerere & Hill, 2001). The losers, once again, are likely to be rural peoples (cf. Twyman, 1998; Alexander & MacGregor, 1999).

In terms of the new water architecture, it must be remembered that the impetus for these reforms is top-down. It is fuelled by donor money. It is guided by engineers and management consultants. As a sectoral reform process, private companies stand to benefit greatly as well: more dams, more boreholes, more and better delivery systems. Ironically, despite the language of 'participation' and 'subsidiarity', water now comes under central state control. And, in the context of the Zimbabwean state, this is terribly problematic. Somehow, one gets the feeling that the entire exercise is in fact a simulation of 'reform', that the process sits lightly atop entrenched interests in a deeply divided society. To be sure, activities will be undertaken as long as donor capital is available. They will, however, take their own course as determined by the political logics of Zimbabwean society – all in the name of equity, sustainability and participation, of course.

3.2 National

Part of the problem with liberalism is its baseline assumption that the state is separate from civil society – that each is an 'actor' with 'interests'. So, in terms of the liberal peace, a primary way to ensure 'stability' in the global periphery is to reform state institutions and to create 'more space' for civil society to operate free from state intervention. For liberals, and prior to the end of the Cold War evidence of state failure was debt. After the Cold War, evidence of state failure was debt and non-democratic governance. In Zimbabwe, both of these conditions obtain. Zimbabwe, therefore, stands as a threat to liberal peace.

The Zimbabwean state has always been problematic for Western political interests. However, since the late-1980s this has been moderated by the Mugabe government's adoption of ESAP and the abandonment in fact of its professed revolutionary goals (Dashwood, 2000). Since 1997, however, Zimbabwe's relations with the West have become strained by the government's approach to 'land reform'. International and (Southern) African 'actors' have resorted to the language of liberal peace in the hope of bringing Mugabe into line with neo-liberal thinking: the rule of law must prevail; otherwise, the 'stability' of Zimbabwe and the entire region will be compromised.

The water reform process fits snugly into the lexicon of ESAP conditions: decentralisation, privatisation, desubsidisation. It also fits with the cross conditionalities of democratic governance: stakeholder management, lowest appropriate authority, and the like. It does not, however, fit very well with current problems over land reform. How are we to understand the contradictory trends of land and water reform? Do not the failings of the former jeopardise the success of the latter? Is it not somehow ridiculous to envision water reforms as taking place in a closed sector in light of the myriad problems created for canal systems and syndicates like ORIC by land invasions?

In order to better understand these contradictory events, it is necessary to discard a liberal understanding of state/society relations. The links between state and society are more usefully characterised in the Gramscian sense as 'organic'. For Moore, 'If the state is internally differentiated and is itself a site of struggle, then "the state is no longer to be taken as essentially an actor, with the coherence, agency, and subjectivity that term presumes"… Rather, the "state can be opened as a theatre in which resources, property rights, and authority are struggled over"' (1993: 389, quoted Mitchell and Watts respectively). Zimbabwe is a post-colonial state form whose legacy is one where 'the imposition of new forms of land designation, as between private and public and in the interruption of customary methodologies of interaction with forest, pasture and soil … have exercised the most intimate and often oppressive impact on the daily lives and ways of production of the rural majority' (Grove, 1990 in Moore, 1993: 384).

The way in which the Mugabe regime has sought to manipulate this legacy need not be reiterated here. The important point for our purposes is that reforms undertaken around such a fundamentally important resource as water must take cognizance of this legacy of dispossession, exclusion and oppression. The water reforms proclaim an interest in correcting profound inequities borne of colonial policy. This is an important and laudable *stated* goal. It is both the means and the hidden agenda of the powerful that are questionable, however. Evidence from various experiences with Catchment and Sub-Catchment Council formation shows not cooperation around a shared vision, but the use of an *articulated shared vision* to reposition vested interests at all levels of Zimbabwean society. For example, in the Save Catchment, the City Council of Mutare has 'secured' its water supply through the construction of a 43 km pipeline from the headwaters of the Pungwe River. For this water it pays ZINWA, the national water authority. In turn, the profits City Council make from this water are used to run all activities of the Council – understandable given the dire state of the Zimbabwean economy, but an action against the spirit of sustainability. Indeed, ZINWA itself is not so much concerned with integrated water resources management as it is with selling water at a profit. At the same time, mining and large agricultural concerns do not participate at all in Catchment deliberations. The Council itself has taken on the character of a special interest group representing the abiding concerns of small and large commercial farmers over a 'secure' water supply. Donors have an interest in seeing the water sector reformed. Their interests overlap with many genuinely concerned groups and individuals in Zimbabwean society. Those at the highest echelons of state power are concerned with not losing control over the resource itself and with maintaining their own positions. In other words, powerful social forces are repositioning themselves around a scarce resource in order to maintain or augment their position. They are having to do so in the shadow of the difficult conditionalities attached to the liberal peace. None of this should be surprising. Zimbabwe is an embattled state form – social forces should be expected to act accordingly.

4. Conclusion

According to the UNDP (2000: 170), in Zimbabwe 21% of the population lack access to safe water, 29% to health services and 48% to adequate sanitation. Fully 41% are not expected to survive to the age of 40. Water reforms are necessary. Without them, these statistics will only worsen. But the laudable goals of the reform process are fundamentally compromised by liberal peace conditionalities. Water is at the heart of human development; it is a central feature of all human activity. Its 'management' cannot be hived off into a 'sector', especially one which must pay for itself. If it is, it is the urban, peri-urban and rural poor who will suffer. As illustrated above, the powerful are already repositioning themselves to ensure continued 'water security'. The liberal obsession with the market is leading a race to the bottom not only in Zimbabwe, but throughout Southern Africa. Given its powerful backers, however, it is unlikely to abandoned any time soon. If nothing else then, what must be avoided is the extension of this dogma to water. Not because it will lead to 'war' – for as Asmal points out above, there is little proof of that – but because it is the right thing to do.

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Water resource management: the challenge of integration in Zimbabwe's water sector reform process

B.N. TAPELA

School of Government, University of the Western Cape, Private Bag X17, Bellville, 7535

nompst@hotmail.com

ABSTRACT

Zimbabwe's water sector reform process has made provision for Integrated Water Resources Management (IWRM). The institutions that have emerged, which include ZINWA, Catchment Councils and Sub-Catchment Councils, seek to implement the water reforms within an Integrated Catchment Management framework. However, apart from these new ICM institutions, the implementation of IWRM includes other sectors and actors. In particular, the government's decentralisation policy has established the Ministry of Local Government's Rural District Councils (RDCs) as the basis planning and coordinating institutions, at the local level, for the Integrated Rural Water Supply and Sanitation Programme (IRWSSP). It is through the RDCs that the other sectors implement water-related projects.

It seems therefore that the integration of water resources management is currently taking place within a parallel process, by the ICM institutions and the IRWSSP institutions. While there seems to be some coordination at the higher levels, there is a lack of integration and coordination at the community or village level. The challenge therefore seems to be to integrate the activities of the catchment and sub-catchment councils and those of the IRWSSP institutions, in a situation where the administrative boundaries overlap with the catchment boundaries. The challenge of integrating water resources management in Zimbabwe is particularly illustrated by the issue of levies for the use of water, and demand and supply management. This paper examines the problems of translating the new water policy into practice. Focus is on the Save Cachment Council in Eastern Zimbabwe.

Water demand management, natural resource reconstruction and social adaptive capacity: a case study from Kolomo, Zambia

Anthony TURTON[1], Chitaku MUCHELENG'ANGA, Esther MBAO,
William MUSONDA, Liswaniso MUKUBESA & Margaret NG'OMA.

African Water Issues Research Unit (AWIRU), University of Pretoria, South Africa
National Institute for Scientific and Industrial Research (NISIR), Lusaka, Zambia

[1] art@icon.co.za

INTRODUCTION

The African Water Issues Research Unit (AWIRU) at the University of Pretoria and the National Institute for Scientific and Industrial Research (NISIR) in Zambia are jointly executing a project on Water Demand Management (see Turton *et al.,* 2000). The project aims at understanding the various social components in the principle of "Adaptive Capacity" and "Natural Resource Reconstruction". Adaptive Capacity refers to the ability of a social entity to adapt to changes in its environment in order to survive (Turton, 1999; Turton & Ohlsson, 1999). Natural Resource Reconstruction is a condition whereby the natural resource-base (water) is being rehabilitated (Allan & Karshenas, 1996:127-8), and is taken as a proxy indicator for sustainability. The research project is being funded by WARFSA and is located at eight different research sites in two different countries (Botswana and Zambia). This paper refers to the preliminary findings from Kolomo in Zambia, which is one of these research sites.

PHYSICAL CHARACTERISTICS

Zambia is located between latitudes 8 to 18 degrees South of the Equator and Longitudes 22 to 33.5 degrees East of the Greenwich Meridian. With a total land area in excess of 752,000 km^2, the country lies on the great African plateau and is generally flat with hills in the extreme North East and the escarpments in the South dividing the Luangwa and Zambezi river valleys from the plateau. The average height is between 900 to 1,400 metres above sea level. Four major rivers drain Zambia - the Luapula/Chambeshi in the North form part of the Congo River Basin; while the Luangwa in the East, Kafue and the Zambezi traverse the Western and Southern parts of the country forming part of the Zambezi River Basin. The Congo - Zambezi Watershed separates the two river systems from each other. Zambia has a seasonal rainfall that comes in summer between the months of October and March, with precipitation decreasing from North to South, and from East to West. The Northern parts receive an average of between 1,000mm to 1,200mm of rainfall annually. The central parts receive between 800mm to 1,000mm while the rain shadow areas covering major river valleys receive precipitation of between 500mm to about 900mm annually.

Kalomo is located in the Southern Province of Zambia and receives an unpredictable rainfall towards the end of October that rarely exceeds 800mm/a, making farming a risky business. With a total area of 15,000 km^2, Kalomo has a population of 143,000 people according to the 1998 estimates. The District is estimated to have about 35,000 households of which about 70% live under conditions of poverty. At least 97% of the population is engaged in agriculture on the sandy-loam soils, which support the growing of maize, tobacco, sunflower and groundnuts. Cotton, fruit and vegetables are also grown in parts of the district. There are three constituencies (Mapatizya, Kalomo and Dundumwenzi) under four traditional rulers (Chiefs Sipatunyana, Simwatachela, Siachitema and Chikanta). Kalomo lies astride the Great North Road 120-km north of Livingstone and about 400-km south of Lusaka. A linear settlement pattern is observed along the road and rail transport routes that pass through the district. Towns such as Zimba and Kalomo lie along these transport routes and are typical of Zambian urban settlements along the line of rail. With an average population density of about 8.6 persons per km^2, Kalomo is sparsely populated.

SOURCES OF WATER

The major sources of raw water for the Kalomo township supply are from dams. These include the Railways and Williams Dams from which raw water is pumped to the treatment plant in Kalomo town. The Railways Dam was constructed in the 1940s to supply water to the railway compound. The dam wall is concrete with a height of about 127.5metres, but siltation has reduced the storage capacity considerably. Williams Dam was constructed in 1953 by a local farmer for irrigation purposes and is an earth dam with a concrete spillway. This dam was connected to the Municipal water supply scheme in 1986 under a World Bank assistance project, while rehabilitation of an electro-mechanical system at the intake was done in 1995 through an African Development Bank (ADB) loan. The dam has since lost its holding capacity due to the collapse of the wall. The low storage and loss of capacity of the two dams has adversely affected the Kalomo township water supply. Five boreholes were drilled in order to augment supply, but these are inadequate. Treatment of water is limited, as the two treatment plants are not fully functional. The railways treatment plant, consisting of a pressure filter, was built in the 1950s, but has not been operational since 1991 due to lack of maintenance and spares. The other treatment plant consisting of two settling tanks, six slow sand filters and two clear water reservoirs was constructed in 1974 by the Department of Water Affairs (DWA) with rehabilitation programs in 1986 and 1995 with ADB loans. This is a modern and conventional slow sand filtration system. Treated water is stored in raised reservoirs with a total capacity of 1,785 m^3 with a daily demand of up to 1,942 m^3. Government estimates show that about 4,205 inhabitants of a total population of 12,773 were being serviced in 1996. The remaining 8,568 people found in informal settlements such as Mawaya, Magrimondi and Bridge Compound are dependent on public standpipes. It is estimated that on average, about 428 people share one standpipe.

Daily water consumption is around 971 m^3, but losses account for more than 50%. This has resulted in the general daily water demand being estimated at about 1,942 m^3. However, the treatment plant capacity is only 3,000 m^3/d with frequent breakdowns. This means that water rationing is commonplace and that induced scarcity is endemic. Sources of raw water for the rest of the population are in the form of dams, streams, rivers, boreholes, shallow wells and dambos. These sources are mostly unreliable and are prone to disease and desiccation. A number of NGOs are operating in the area, mostly involved in development programs related to water supply and sanitation. The period between 1991 and 1996 saw a prolonged drought in the Kalomo area, resulting in the dropping of ground water levels. A large portion of the District lost access to reliable water sources at this time and poverty is increasing as a result. People walk long distances to fetch water. At one time, children as young as five years covered distances of 15-km in order to fetch water. According to the 1995 survey done by the Community Management and Monitoring Unit (CMMU) of the Water and Sanitation Sector Reforms, of the 299 water points for rural water supply, 110 were not working due to various reasons.

COLLECTION OF DATA

The data gathering in Kalomo took place between 7 - 15 March 2001 and involved all 5 members of the team under the leadership of the Local Research Partner (LRP). The team was accompanied by Engineer Cledwin Mulambo, the Senior Engineer responsible for water and sanitation at the Ministry of Local Government and Housing. This followed a pledge of support received from Government to assist in the provision of vital logistics for the duration of the data collection phase. The Permanent Secretary wrote letters to the District Administrators in the respective districts. In support of this, the LRP wrote letters directly to all of the stakeholders in the project areas to indicate the start of the data-gathering phase.

The team started gathering data from various settlements in Kalomo, followed by Zimba 40-km to the South. Three unplanned settlements were polled - two in Kalomo town (Mawaya and Magrimondi) and one in Zimba (Mawaya Zimba). In addition to this, another three settlements were polled - Green Acres and Mwaata, consisting of medium cost houses, and Boma consisting of a combination of low, medium and high cost houses. In all cases data was collected by using a questionnaire with a target of 220 questionnaires in total. The Enumerators interviewed the respondents and their responses were recorded on the questionnaires. The categories of the respondents were broken into what was knows as Supplier (with a target of 20), User (with a target of 200) and Other**.** Entry into the communities was first established through the community leadership. As indicated earlier, letters were written to the District Administrator and the Council Secretary in order to introduce the team and its programme. On arrival in the field, meetings with the District Administrator and later with the Local Authority leadership were held. Community leaders such as Water Point Chairpersons were also briefed before the data gathering exercise was commenced. A general walk through each of the communities was first executed in order to establish some conceptual map of the area in question as no formal maps existed. Any special features of an area were noted. The research team then went out into the field to an arbitrarily selected starting point and fanned out individually along a determined straight line sampling and interviewing households. Where possible, selecting every 5th household for sampling ensured randomness, but this was not always practical. The team also held focus group discussions where qualitative data was gathered as relevant. Any spontaneous data that was collected was noted on the back of the questionnaire sheet while other details were recorded in notebooks brought by the team for the purpose. During the evening the whole team met to discuss the findings for the day and to engage in planning for the next day. Preliminary data cleaning was first done by the Enumerators and later by the LRP while still in the field. Subsequently the data was evaluated by the LRP using simple scatter scores and percentages of the responses. The original data sheets are being stored as they contain a wealth of information that can be relevant to subsequent research projects.

PRELIMINARY FINDINGS: RESPONSES BY "USERS"

Most people (58%) in the area do not use public standpipes. This can be explained by the fact that this is mainly a rural setting where most water is supplied through boreholes fitted with hand pumps. People do not regard these as being standpipes. Most people (59.5%) do not have metered connections. Most houses are either not metered, or the meters are not working. This is causing concern to the Users whose willingness to pay has been greatly affected by this factor. A significant number of people (37.2%) served by the Commercial Utility have alternative supplies that range from streams, rivers shallow wells, dams and boreholes. These alternatives are mainly used during interruptions of supply from the Utility, which is under severe pressure caused by limitations to the treatment and storage capacity noted above. Many people (50.6%) supplied by the Commercial Utility receive regular bills for their water at monthly intervals (96.78%). Most of those who do not receive bills are individuals supplied by the Commercial Utility through a “cash and supply” system where water is paid for at the time of drawing it at the supply kiosks.

Price was seen by most (65.7%) to be a sufficient incentive to manage water demand. However a significant number (33.5%) indicated that price in itself may not work. Their reasons for this assertion ranged from indicating that those with money could continue to waste water even if they paid for it, and demand could still be high because of carelessness on the part of the consumers. **It was proposed by some that education and not price might work better.** A number of people (49.3%) indicated that they do not receive monthly bills as they paid cash on drawing the water at the kiosk, or paid for water rights every three years to Government. Some said they received free water from the Commercial Utility as employees of the same company or that they belonged to a Water Point Committee, which collected cash from the Users. These were mainly the borehole-supplied Users in the villages. This indicates an element of corruption that undermines both the sustainability and the integrity of the whole system.

When asked about the fairness of the system of paying for water, most respondents (55%) felt that it was fair. For those that considered the system to be unfair, the major reason given was the fact that those on fixed rates felt that they were being cheated by the Utility. Others said that they would only consider the system to be fair if the water supplied was of good quality. **A small but significant group in one of the localities (Mawaya Zimba) said payments being made were not being receipted** and that the community was not being consulted on matters of adjustments in tariffs. A supply of only one water point to about 5,000 residents who are each asked to pay K8,000 per month (K3,500 = US$1) was said to be very unfair, and an increase in the number of water points was suggested to resolve this problem.

Significantly, **the majority of respondents (64%) said they were willing to pay more for water if the supply was more convenient and accessible to them**, especially if brought closer to them. The Users ready to pay more for the service also indicated that they would pay between K1,000 - K6,000 per month (K3,500 = US$1). Most institutions pay between K250, 000 to K1,600,000 per month (K3,500 = US$1).

Most of the respondents (68%) clearly indicated that the current service was unreliable. The biggest complaint on service reliability was that water is being rationed. Most respondents echoed this sentiment. The dissatisfaction with the reliability also touched on the issue of Kiosk Operators (water vendors working for the Commercial Utility) who are not available when needed. A common sentiment was the desire for water supply connections to individual houses in order to reduce walking long distances, in addition to an increase in the number of water points and boreholes. The quality of water was another issue of concern as the Users felt that dirty water was a danger to their health. **Most respondents (60%) were dissatisfied with the quality of the water**. To resolve this problem, a common suggestion was that water needs to be treated, while some said there is a need for education to all, including the Supplier.

Most of the respondents (88%) indicated that they are not satisfied with the amount and type of information that they are given at present by the Supplier, and the need that the Utility should improve its dissemination of information to Users was often articulated. The dissatisfied Users suggested several remedies to improve the situation. These included the use of a public awareness program such as a Public Address System to provide information to the community; the holding of meetings with Users; consultations with the community on matters of common interest; the use of publications such as brochures and regular community visits by the Utility to listen to the concerns of the Users. Significantly, the Suppliers did not mirror this sentiment.

The majority of respondents (80.5%) exhibited an awareness that there is a cost attached to the supply of water. Most (90%) also suggested that Users want a combination of the Government or Commercial Utility to bear the cost of supplying water. **Regarding water charges, 53.4% said that they were fair and reasonable.** Some of the reasons advanced for the unfairness of the charges included assertions that water should flow 24 hours a day in order to attract such high bills as the consumers are merely paying for wind. In order to satisfy them, these consumers demanded that charges should be reduced from the current K10.00 per 20 litres from kiosks or K8,000 per month (K3,500 = US$1) for public stand pipes, to something lower. **The disgruntled consumers also indicated that there is a need to meter their supply so that they only pay for what they consume.** The provision of subsidized water to the poor and consultations with the community were also suggested as measures to enhance fairness.

Only 37.5% of the respondents were satisfied with the current levels of accessibility. The dissatisfied group said that in order to rectify this water should either flow continuously, or that the rationing should stop. Others said that the number of kiosks, standpipes and boreholes should be increased. This was evident in one of the townships (Mawaya Zimba) where about 5,000 households use one standpipe for their supply. The provision of clean water, own house connections and the bringing of water closer to home (some walked at least 3-km to fetch water) were also highlighted. Most walked more than twenty paces but less than 3-km to fetch water, which was done three times in a day as the average frequency of drawing water.

Typical of any Southern African situation, men rarely drew water. This was left to the women and children to do. It was usually the unmarried men that drew their own water. The water is commonly stored in 20 litre plastic containers and rarely in buckets, clay pots and tanks. The water was used for drinking, cooking and washing. In some instances where this was possible (distance and cost allowing), gardening was done and in very rare cases water was used for low-level types of industrial production. Though this is a very important agricultural area, most of the respondents did not own animals due to problems of disease, or the fact that the urban setting may not allow such practices. Those with animals watered them at dams or rivers rather than at standpipes.

Most respondents (72%) said that they do not have food gardens, despite recognizing that these are important in their lives, because of the endemic water scarcity. Only 28% indicated that they had food gardens that they mostly kept during the rainy season. The irrigation of gardens was not commonly done (only 33% of respondents do this) using standpipes. Those that do irrigate noted the importance of food gardens as a source of food for the family, or as a supplement for the family income through the sale of vegetables produced. **Almost everyone had the wish to own a food garden but water scarcity was advanced as the reason for their failure.** Water scarcity can therefore be directly linked to the cycle of poverty in the region.

Only 1.4% of the respondents knew the true cost of supplying water. The cost is between K350.00 - K450.00/m^3 (K3,500 = US$1) while consumers were being charged K10.00 - K20.00 per 20 litres in the low-income areas. The respondents were generally ignorant of these facts. Significantly, this ignorance was also found in the Suppliers.

The vast majority (91%) of the people were not aware of the existence of a water conservation strategy in their area. Most (58%) said that government formulated this strategy while the remainder said it was done by the Commercial Utility. Those who were supportive of the existence of a water conservation strategy said that the major elements are stopping the wastage of water or encouraging the conservation of water and keeping water sources clean from pollution. **The majority (95%) indicated their support for such a strategy if it existed.**

Only 14% indicated that they knew what the term sustainability means. Those who said that they knew defined the concept as the maintenance of the pipes; buying spares; the continuous running of facilities; and protection of the standpipe from vandalism. This means that notions of sustainability can be included in an educational strategy. Water was well understood to be a scarce resource in Kalomo (79%), probably as the result of the persistent droughts in the area. This means that the population would be receptive to an education campaign. Responding to the question as to what people did when they came across a water leak, most of the respondents (98%) said that they closed the leak or reported it to the Company or Commercial Utility. **This**

means that there is a strong sense of responsibility within the community that can be harnessed through an education campaign.

On the original source of the water, most respondents (98%) said that it came from God and mentioned specific places such as a dam, river, rain or borehole. Regarding the ownership of water, half of the respondents (52.4%) said that this was vested in the Commercial Utility, a quarter (25.5%) said that God owned it, 13% said that nobody owned it while the rest said that they do not know. The majority (73.2%) said that the responsibility for water falls on the Commercial Utility (73.2%). When asked what roles the respondents played in the prevention of water wastage and contamination, they said that: they closed leaks; were involved in the education of the children and others to conserve water or not to pollute it; carried out hygiene education; used water economically and boiled drinking water.

PRELIMINARY FINDINGS: RESPONSES BY "SUPPLIERS"

A total of 11 respondents in the group of "Suppliers" were interviewed. These were either employees of the Commercial Utility, Department of Water Affairs, the Local Authority, or NGOs involved in issues of water supply.

Concerning the cost of producing and delivering a cubic metre of water in their areas of responsibility all Suppliers interviewed (100%) did not know. However the cost paid by the Users varied between K300.00 – K500.00 per month (K3,500 = US$1) for water supplied in Villages by Village Water Committees from community boreholes, while those in Towns (urban settlements) varied between K10.00 – K20.00 for 20 litres. In the medium cost residential area consumers were paying K350.00/m^3 (K3,500 = US$1) and the high cost residential area consumers were paying K450.00/m^3 according to the Suppliers that were polled. **Investigations revealed that the true cost of supplying water is K450.00/m^3 (K3,500 = US$1) and none of the Suppliers interviewed knew this cost.** Most Users (63.6%) indicated that the tariff was applicable to all. From the comments made by the people in the area, there was confirmation that there was little being done to assist those who were poor to get access to water at a reduced cost. Those that said there were differences in tariffs also said that some consumers were on fixed charge, others were paying between K580.00 – K750.00/m^3 (K3,500 = US$1) while staff members of the Commercial Utility were being given free water. This level of cost recovery was said to be adequate to ensure sustainability by some Suppliers (45.4%). This indicates that **there is no real knowledge about the actual cost of supplying water in the area, and this may account for the lack of capacity** and erratic supply.

Most Suppliers (72.7%) indicated the existence of a water demand management (WDM) strategy in their area of responsibility. Those that said there was a WDM strategy in place gave the key elements of this strategy as: training communities in the use of water; training pump menders how to repair pumps; safe water storage; cleanliness; demand driven training; Participatory Rural Appraisals (PRAs); education to Users; leak detection and reporting/repair; educating people that the supply of water costs money; hygiene practices; the establishment of 5 new kiosks; the development of 4 more boreholes and 2 more dams. **As most of these responses focus on supply management rather than demand management, there is clearly a lack of understanding as to what constitutes a WDM strategy.** Significantly, one of the elements is education on the cost of water, where none of the Suppliers knew this figure themselves.

The majority of Suppliers (90.9%) felt that Users were willing to pay for water. The current tariff structure was said to be able to provide sufficient incentive to manage water demand in a sustainable manner by the majority (63.6%) of Suppliers. **Most Suppliers (90.9%) were aware**

that Users were willing to pay a higher tariff if water was made more accessible and convenient. This is in harmony with the finding in the Users poll.

On the impact of water accessibility to the poor, **the Suppliers gave varied statements, all indicating that they are not in touch with the reality on the ground**. Some of these are as follows: It is positive in that distance is short and the cost is affordable. The cost is paid in kind by the poor. Water is not sufficient so the poor queue up. There is no scheme to cover the poor hence all pay the same price. People are opposed to payment, as there is no water. Some are forced to draw free water from Southern Water and Sewerage Company (SWSC). The very poor are exempted from paying. The community takes care of its poor people. People are able to spend time economically due to the availability of water. Poor people now have food security through gardens. The people have more time to do farming and make more money from other activities such as gardening. Abundant water means less poverty.

The number of public standpipes in various areas was found to be inadequate. It ranged between 1 - 5 in urban areas and 0 - 73 water points in rural areas. Most served vast areas of land with some people walking distances of greater than 3-km. The number of plots serviced by the Suppliers depended on the locality (urban or rural). The number ranged between 250 and 973. However, the concept of “plots” is an alien one in Zambian village communities. Perhaps terms such as “households” or “families” could have been more appropriate.

Only urban settlements in medium or high cost areas had metered connections. The existence of meters is not uniform however. In one instance 672 out of 973 plots have meters, whereas in another area 2 out of 300 plots were metered. **This is significant given the general public support for metered connections.**

Almost half of the Suppliers (45.4%) operated in an area where Users never received water bills. This is understandable in a village setting where monies were collected by the communities themselves without bills being sent out. Another element is the system of paying for water at the time of drawing it. A monthly interval between bills was said to be the frequency with which bills are received. All metered Users were willing to pay for water as indicated by the unanimity of the Suppliers on the question (100%). **Suppliers also indicated that most metered Users actually paid for water.** The figures on this ranged between 74.4% to100% depending on the locality. **This is significant as it is supported by the poll that was done on the Users.** It therefore indicates that meters would work, but the cost of installing them makes them prohibitive.

Most Suppliers (72.7%) said that Users were sufficiently educated about all of the issues that impact on the sustainability of water supply in their areas of responsibility. Those that disagreed with this added that there was a need to launch information campaigns in order to educate the Users on the use of water. **Significantly, a large number of Users also called for an education campaign, but one that included the Suppliers as well.** In launching an educational campaign, the Suppliers named the key elements to be included. These were: the Mission statement of SWSC; the importance of water; Users education in sanitation/water maintenance; the operation and maintenance of a water supply system; hand pump maintenance; village level operation and maintenance (VLOM); the training of women masons; the safe storage of water; the need for User fees to be paid; costs of supplying water; the WASHE concept; and the conservation of water. The target audience was identified as being high density/illiteracy areas, women, V-WASHE Committees, caretakers, pump menders, domestic customers, all consumers of water, leaders like chiefs and water committees. **Most Suppliers (90.9%) claim that there is community consultation regarding aspects of water supply that affect Users directly.** Most Suppliers (81.8%) also claim that community consultation has been very successful. **This is at odds with the opinion polled from the Users.**

On the relationship between the Supplier and Users, the majority of Suppliers (72.7%) indicated that it was healthy. Some said that Users complained about the hours of operation. Some Suppliers indicated that the relationship was bad in areas where sewer lines are located as Users do not want to pay an additional 50% of water charge as sewerage fees.

CONCLUSION

The tentative conclusion is that water supply is under severe stress in the Kalomo area. Significantly there is a high willingness to pay, even in the face of the endemic poverty in the area. There is also a high willingness to be metered, but the costs of installing this are too high. The Users are generally unaware of the existence of a WDM strategy in the area, even though the Suppliers believe that one exists. When spoken of, the WDM strategy really focuses on supply rather than demand management, so the concept of managing demand is relatively alien in the area. Nowhere is there an understanding of the true cost of water supply, even among the actual people responsible for the supply process. These all combine to suggest that a training programme is needed before WDM can be introduced. Elements of corruption were found. These centered mostly on people who were unable to pay the full cost being asked, so they negotiated with the relevant officials who then supplied them water in return for cash that was not entered into a receipt book. If the Suppliers could manage this better, then the income stream could be improved along with the reliability of service delivery, which is hopelessly inadequate.

Significantly, the Users polled seem to have a strong sense of justice or fairness, and they are willing to pay what they consider to be fair. There is a big gulf between the Suppliers and Users however. The Suppliers seem to think that the Users are happy with their services, whereas the Users are calling for greater communication and consultation. There is reason to believe that if this is provided, then the overall sustainability of water supply could be improved in the area. Elements of a WDM programme could include three cardinal components: pricing and the true cost of water provision; accessibility to water and the implications of that both in terms of health and in terms of the enhanced willingness to pay; and education of both the Users and the Suppliers of water.

In reality, no formal WDM strategy exists in the area, and no evidence of Natural Resource Reconstruction can be found. If anything, resource degradation is the order of the day, ranging from the over abstraction of boreholes to the leakage of untreated sewage into areas that pose a direct health risk to water resources. One of the really interesting elements of this project, is the way that the field research changed the perceptions of the Enumerators, all of whom come from various Government Ministries. In all cases, the Enumerators were initially of the opinion that Government was doing a good job before the field trip, whereas after the field trip all of the Enumerators said that their eyes had been opened to the harsh reality on the ground. This seemed to motivate them further in wanting to change things for the better, which they all pledged to do on return to their respective Ministries.

ACKNOWLEDGEMENTS

The research team gratefully acknowledges the support of WARFSA for this project. In addition to this, the various Government Departments are also thanked, along with the District Administrators and Traditional Leaders who provided the support needed for the project. Finally, the whole team is also thanked for their enthusiasm, dedication and commitment to the arduous job of conducting survey-related research in Africa.

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Data Gathering in Progress.

Catchment Management Agencies for poverty eradication in South Africa

Barbara SCHREINER[1] and Barbara VAN KOPPEN[2]

[1] Chief Directorate Water Use and Conservation, Department of Water Affairs and Forestry, South Africa
[2] International Water Management Institute Africa Regional Program,
Private Bag X813 Silverton 0127, South Africa

[2] b.vankoppen@cgiar.org

ABSTRACT

This paper discusses the changes in the water law under the new dispensation in South Africa from a poverty perspective. The focus is on the early experiences of implementation of one of the components of the National Water Act: establishing Catchment Management Agencies. From the diversity of experiences in decentralizing integrated water management, key areas emerge where steering by the government is crucial to establish pro-poor, developmental Catchment Management Agencies.

Keywords: *poverty, water, integrated water resources management, catchment management agency, water law, South Africa*

1. INTRODUCTION

The National Water Act (1998) of the Republic of South Africa (RSA 1998) is not only widely recognized as the most comprehensive water law in the world, but also stipulates, clearer than elsewhere, that water is essentially a tool to transform society towards social and environmental justice and poverty eradication. As such, the National Water Act is undoubtedly a masterwork among the socio-political changes of the 1990s in which the Apartheid regime was replaced by a democratically elected government. The new law represents a fundamental legal reform in the country, because it shifted the locus of formal water control from riparian water title holders, largely consisting of the white minority, to the new government as custodian of the nation's water resources. However, this legacy of the past continues to influence the implementation of the new Act, an endeavor that the Department of Water Affairs and Forestry has started through a broad array of simultaneous actions.

This paper focuses on the implementation of a key component of the National Water Act, the establishment of Catchment Management Agencies (CMAs), from the perspective of the contribution to poverty eradication in rural South Africa. Although the establishment of CMAs is still very recent and limited to pilot sites, insightful lessons are emerging for future developments. First, we conceptualize the contribution of water and integrated water resources management to poverty eradication (Section Two). Section Three sketches the historical changes in water legislation and presents the relevant components of the National Water Act. In Section Four, three modes of CMA establishment are described, based on evidence from pilot processes. The conclusions highlight areas of critical concern for the new developmental CMAs if they aim to contribute to poverty eradication.

2. WATER FOR POVERTY ERADICATION

Almost 50% of South Africa's population is income poor, spending less than R353 per adult equivalent (USD60) per month. More than one quarter, 10/12 million people, are without clean water. Child malnutrition is widespread. National stunting rates for young children range between

23% and 27%, and are as high as 38% in poorest 20% of households. 33% of children display marginal vitamin A status. Unemployment rates in 1999 were 52% for African women between 15 and 65 years, and 37% among men (Statistics South Africa 1999). As elsewhere in the world, the majority of the poor, 70 %, live in rural areas. In no other country in the world income distribution is so unequal as in South Africa. The distribution of land resources is also highly skewed. 13% of the population owns 87% of land (Lahiff 1999; Cousins 2000). Gaps in access to water appear even wider. 95% of water for irrigation is primarily used by large-scale farmers, while smallholders have access to the remaining 5% (De Lange 1998). In the Mhlatuze Basin in Kwa-zulu Natal, more than 97% of available water resources are used by 10% of the population, although a small part of the benefits from this water use does trickle down (Steyl et al. 2000). Combating this poverty is the primary goal of the government of South Africa and therefore of the Department of Water Affairs and Forestry, through the National Water Act.

In South Africa and elsewhere, poverty, poverty eradication, and water are linked in many respects. Poverty is a state and process of multi-dimensional human deprivation affecting economic, health-related, psychological, socio-cultural, legal, and political facets of wellbeing (World Bank 2000/2001). This links to the various ways in which water serves human life. Household water for drinking, hygiene, and cooking contributes to health and nutrition. Water as input in rural productive activities contributes to income generation through farming, livestock, forestry, fisheries, power generation, navigation, and small and large industries. The esthetic and recreational values of water allow tourism. But water also brings adversities, like floods and soil erosion.

Water deprivation is intrinsic to poverty. Poor people lacking the assets and means to access clean water are forced to drink water of low quality, often against excessive labor or cash costs especially during periods of drought. Water-borne diseases are aggravated because poor people lack access to health services. Adversities of flooding, inundations, landslides, and other natural and human-made water-related disaster tend to hit poor people hardest because their lack of alternative means forces them to occupy flood-prone and risky lands. The impact of negative events like drought and flooding is worst for the poor and vulnerable. Without any buffer for recovery, one lost harvest, one illness, or one debt can easily result in a downward spiral from which it is extremely difficult to escape.

Being poor often also means being denied the right to water to produce. The development of infrastructure for economic development in society tends to serve those who already have the land, capital, skills, and markets to make use of water. Even though there is evidence that small farmers use their limited land more productively than large farmers, among others through water harvesting and irrigation, efforts to develop technologies fit for small-scale use used to be limited, although they are slowly increasing. Nevertheless, droughts continue to hamper poor people's production, to limit their incomes, and to intensify crises for which they have no resilience. This blocks millions of rural people into a labor reserve dependent upon wage labor in large-scale farms, mines, industries and services, and on food purchased on the markets of the large farms. The fact that small-scale enterprises 'fail to provide a decent family income' is, ironically and naively, even used as argument to justify continuing deprivation of poor people from the opportunities that water represents to use scarce land and other resources more productively.

Poor people's water deprivation is the result of and perpetuated by society's hierarchies in water resources development, management, and protection. Few obtain the assets to use large quantities of water and acquire the socio-political and legal power to assure their permanent access to water. Without the assets to capture water as effectively as the more powerful, poor people are already excluded from water decision-making. This is further reinforced by poor people's general social exclusion from public governance. Poor people's ability to effectively participate in public decision-making is hampered by sub-standard education, literacy, language knowledge, mobility, access to information and social and political organization both within and outside their neighborhoods. Moreover, the rules and regulations that shape their communal lives tend to be ignored. The poor, the only people in this world who suffer from life-threatening water-scarcity, become the 'nobodies', internalizing prejudices and less self-confident to challenge a hostile outer world. Thus, poor people's low water demand is a social construct.

As a corollary, water resources development, management and control can contribute to poverty eradication if it boosts water demand among the poor for their improved wellbeing in terms of health, incomes, assets, resilience, socio-political and legal inclusion, and say over their lives. We will analyze the recent events in South Africa from this perspective.

3. TRANSFORMING WATER LAW UNDER THE NEW DISPENSATION

Changes in Water Law

Before 1994, jurisdiction over water followed the geographical segregation under the Apartheid regime. The Department of Water Affairs served the former white Republic of South Africa, while in the homelands water authority was vested in the homeland governments, locally represented by tribal chiefs and councils. Whereas each homeland government implemented this responsibility in its own way, rural drinking water supply and the development of state-subsidized irrigation schemes in collaboration with Development Corporations were often part of homeland water affairs.

In the former white RSA, water rights were primarily vested in riparian right holders. Commercial farmers, an important constituency of the Apartheid government, were well served by the Department of Water Affairs through highly subsidized scheme and dam development. Gradually, however, DWAF started shifting focus to other important water users, such as power generation and industries, and also intensified water quality management. By mid-1980s, the first basin studies were undertaken, in collaboration with consultancy firms that accumulated expertise for the area in which they were active. The first ideas for Catchment Management Agencies also originate from that period (DWAF 1986).

Among water users in the white former RSA, a considerable degree of self-management had crystallized. Elected Irrigation Boards managed large-scale irrigation schemes and their representatives participated effectively in national farmer organizations. Portions of rivers, in which farmers had built weirs, were governed collectively. Large-scale water users also started to organize at basin level. For example in 1992 the Olifants River Forum was initiated to promote more coordination between the mines and the Kruger Park downstream of the Olifants River, and the mines, industries, and ESKOM (electricity generation) upstream, in a common pursuit of a 'healthy river'.

The transformation of the water law was integral part of the political events arising out of the end to the Apartheid Era in 1994. Under eminent leadership of the Minister of Water Affairs and Forestry, Kader Asmal, a process was launched to incorporate public views nation-wide and to harness global knowledge for the formulation of the National Water Act, which was finally promulgated in 1998. In the new Act, water management ceased being an end in itself, but became explicitly instrumental to the country's overall economic development goals in which poverty eradication and redress of inequities figure high. The Act further includes preservation of water for ecological purposes, integration of surface and groundwater, gradual decentralization of water management to the lowest appropriate level and self-financing, public participation and community involvement, and, the shift from administrative to hydrological basin boundaries for water management.

In promulgating the new law, the government abolished the former system of riparian law and took over all water management authority as custodian of the nation's water resources. With the abolishment of the homelands DWAF's jurisdiction became nation-wide. However, the status quo was maintained in the sense that the National Water Act recognizes all water use in the two years preceding the promulgation of the Act as lawful, and, hence, also accepts the prevailing inequities as starting point. Moreover, there were no retrenchments in the government administrative services in the new dispensation, resulting in the new approach to water resources management being implemented by many of the officials responsible for implementing the previous inequitable legislation.

Perhaps the greatest achievement in formulating the National Water Act is that the most diverse stakeholders in the 'Rainbow Nation' not only endorsed the law but that they also took pride in this unique piece of legislation.

Pro-poor Components of the NWA
Components in the National Water Act that can contribute most concretely to poverty eradication, besides pro-poor CMAs, are the following.

a. The Water Reserve and drinking water supply services
The Water Reserve, which is allocated before any other use, includes an Ecological Reserve and basic water needs for human consumption. Current policy has set these basic consumption needs at 25 liters per person per day. Moreover, in 2000 the government decided to provide the first 6000 liters per household for free.

Implementation is primarily a matter of infrastructure development and institution building to overcome the backlog of the Apartheid Era, which ranks South Africa at only the 31st place of all African countries in performance of rural water supply. Since 1994 DWAF became responsible for this implementation, as elaborated in the Water Services Act of 1997 (RSA 1997). While former homeland governments had experience with rural water supply, including reticulation, this was a new task for DWAF, because till then it had only supplied bulk water to water boards and municipalities in the white areas. The Mvula Trust was established to provide the needed institutional and technical support. At longer term, the new democratically elected local governments and municipalities are expected to take up the responsibilities of water reticulation in rural areas.

b. Compulsory Licensing
The National Water Act includes the option for DWAF to call for compulsory licensing where and when needed. A project of compulsory licensing concerns all water users in a specific area. It cancels all existing licenses and replaces these on the basis of a new allocation schedule. Redressing inequities from the past and addressing over-allocation are key criteria for the reallocation. Implementation of compulsory licensing is currently being prepared for highly water-stressed pilot areas.

Recent calculations of the Ecological Reserve in some of these water-stressed basins indicate unexpectedly high quantities of water needed to maintain the aquatic ecosystem, and, hence an even stronger need for compulsory licensing and cutting back water use from current users. However, DWAF is considering, among others, *not* to cut water used by historically disadvantaged small-scale users.

c. Schedule 1
A tool for water authorization that may favor poor people further is the so-called Schedule 1 of the NWA, which stipulates which water uses are permissible under any condition. According to the National Water Act this concerns water used for reasonable domestic use, livestock other than feedlots, and 'small gardening not for commercial purposes'. However, it is increasingly realized that farming and gardening by poor farmers is often market-oriented, at least for a part of the harvest. It is certainly expected to become more market-oriented in the near future. Therefore, it should be considered whether to extend permissible water use under Schedule 1 to include the

use of low volumes of water on say, less than two hectares, or for an income around or slightly above the poverty line. This would also accommodate for the practical impossibility to trace millions of low-volume water users in water-stressed basins for formal registration and authorization.

d. Cooperative governance
Generally, the South African government strongly emphasizes the need for strong horizontal and vertical cooperative governance between the various government agencies. Thus, better collaboration between the Department of Water Affairs and Forestry and the National and Provincial Departments of Agriculture is crystallizing. This has already led to a new national policy to increase productivity of agricultural water use by smallholders that encompasses water, access to land, markets, credits, skill development, etc.. Links have also been established with the Presidential Integrated Rural Development Program that is to be implemented through the Local Governments.

Cooperative governance between DWAF, the Local Government, and other line agencies, in close consultation with communities, is especially important for pro-poor water development and management in rural areas. Local Government is constitutionally the agency responsible for new water supply and sanitation services. It is also responsible for storm water management. In the near future, the Local Government is also expected to become more important in promoting water development for productive uses. An integrated approach to water development and management with strong people's participation is most essential in rural communities, where the same water source is used simultaneously for drinking, domestic and a divers range of productive purposes. Sanitation and waste management often directly affect other water sources as well. Water development for one group of villagers easily affects other users jeopardizing fulfillment of people's basic needs. Cooperating government services that respect indigenous water tenure and foster community-based integrated water management could considerably improve poor people's benefits from water.

Catchment Management Agencies
The new governance body through which many components of the National Water Act will be implemented is the Catchment Management Agency. The Minister of Water Affairs and Forestry will establish CMAs in the 19 Water Management Areas of South Africa and gradually assign many water resource management powers that are currently carried out by the DWAF to these new governance structures. Ultimately, the CMA will carry out functions such as water resources planning in the catchment, registration, water charge collection, and water authorization. Public participation and representation in the establishment process and in the later Governing Board and activities of the CMAs are legally required. In the Governing Board the interests of water users, potential water users, local and provincial government and environmental interest groups will be represented. CMAs are to become self-financing.

This major change from a centralized management approach based on command and control to a decentralized participatory model based on cooperative governance and coordination through CMAs is currently being implemented. Parallel to the process of establishing CMAs, DWAF itself is being restructured. The remaining national functions of DWAF are being defined, DWAF regional offices are being restructured and preparations have started in restructuring some DWAF regional staff into technical support structures of the CMA in the new Water Management Areas. As long as CMAs are still being established and maturing, DWAF continues carrying out all functions that are not yet taken up by CMAs. The focus of the rest of this paper is on the pioneering efforts to formally establish CMAs through public participation.

4. MODES OF CMA ESTABLISHMENT

Since the earliest proposals for catchment-based management 15 years ago, DWAF and the public, or the public alone, launched numerous new initiatives countrywide for managing sub-catchments or catchments. The nature of these initiatives highly varies and depends upon the socio-economic and ecological context, main drivers of the process, availability of financial support from DWAF or donors, historical availability of technical expertise and specific projects, composition and work style of regional DWAF offices, etc.. There is also considerable difference in the interpretation of the purpose of the establishment process and the extent and form of public participation, representation, and feedback loops. In this early pioneering stage with new forms of management, variation is most fruitful, because it highlights the wide range of options open for the future. In order to give an impression of the variation, three diverging modes of CMA establishment and public participation are elaborated below, based on evidence from the Olifants River Basin and the three Water Management Areas in Kwa-zulu Natal. The focus is on differences so there is no attempt to give a complete description of each approach (Muller 2001; Ligthelm 2001).

Formulation of a technical proposal for CMA establishment

The first mode of CMA establishment can be characterized as a 'formulation of a technical proposal for CMA establishment'. The main purpose was to submit to the Minister a formal proposal for a CMA that includes the available technical data. (White) technical consultants with historic technical expertise in the areas concerned were appointed by DWAF to play active part in the process of CMA establishment and proposal writing. The public participation processes built upon earlier initiatives of public participation, especially by large-scale farmers, mines, tourist industry, ESKOM (electricity), and industries. In fact, the option was considered that these existing forums and other public institutions themselves would become the CMA, who then would take the process from there. This option was strongly supported among these public initiatives, but ultimately rejected by DWAF who wanted the future CMAs to be inclusive from the start onwards.

Two rounds of public meetings throughout the basin were organized, also in order to bring the historically disadvantaged groups in society on board for information and consultation. Written invitations for these public meetings were sent to all contacts of DWAF and the consultants, including local governments, tribal authorities, traditional healers, etc.. New contacts between DWAF and rural communities were established in this way. The public meetings consisted primarily of information provision on the concept of CMAs and basin-level management with public participation, and, in the second rounds, on the structures that the consultants and DWAF proposed for the future CMA. The main language was English. Invariably, poor rural communities raised the issue of drinking water problems. For those and other problems, people were referred to the relevant other authorities within DWAF. The CMA was seen as one of the many parallel processes in which DWAF interacts with the public and tries to avoid duplication.

The first round of public meetings was also used to invite volunteers from the historically disadvantaged communities to take seat in a Stakeholder Reference Group. This small group, partly consisting of the former contacts of the consultants and DWAF, discussed the CMA proposal more in-depth. As the black participants were not invited to clearly represent a constituency, there were seldom feedback loops to others.

A draft proposal, which the Stakeholder Reference Group has not seen anymore, has been finalized. This will be either submitted or revised depending upon the formal guidelines for proposals to the Minister on CMA establishment that are currently being finalized. Inclusive public participation is a key criterion for acceptance in these guidelines. A newsletter will soon be made to inform stakeholders about the state of affairs.

Bottom-up reconnaissance for CMA establishment

The second approach, that we call a 'bottom-up reconnaissance for CMA establishment' aimed at informing historically disadvantaged communities about the new CMA, at assessing their water-related needs, and at soliciting suggestions for a governance structure that can effectively influence the CMA. It was initiated by DWAF to complement the first approach that was increasingly acknowledged to rely too strongly on those who were already well organized. If small-scale water users were to be brought on board, DWAF also needed to accommodate for the huge arrears in poor communities' information and contacts with DWAF, recognized and effective representation structures, knowledge of English, mobility, experience in state consultation processes, etc.

The main implementer of the process was a (black) social facilitator-cum-community developer. Her network of contacts throughout the basin originated from the anti-Apartheid struggle and ongoing rural development activities, while Local Governments and NGOs facilitated the logistics of the meetings.

Daylong workshops in the local language generated overviews of the problems participants experienced with regard to water. This included drinking water, often as top priority, but also rainfed and irrigated agriculture, and issues indirectly related to productive water use, such as the lack of markets, inputs and training for both irrigated and rainfed agriculture, and frustrations about the slow pace of the land reform. Concrete suggestions to organize in multi-tiered small-scale water users forums for effective representation in the future CMA Governing Board and committees were made. The report of these workshops was included in the technical proposal.

While waiting for DWAF's follow-up on the submitted overall proposal, the social facilitator-cum-development worker continues exploring water-related issues in poor communities. Where needed she mediates between communities and DWAF to solve issues, such as excessive groundwater abstraction by mines, which causes boreholes for domestic water supply in neighboring communities to dry up. Stimulating more people, especially women, to use more water more productively, for example through water harvesting for homestead gardening and trees, is integrated part of this mode of (sub-) catchment management.

Decentralization of integrated water resources management for CMA establishment

In the third approach, 'decentralization of integrated water resources management for CMA establishment', the Regional Office of DWAF drives the process of establishing CMAs in Water Management Areas with additional support of only few hired social facilitators. From the start onwards, the emphasis is on establishing CMAs that are essentially to be governed by water users themselves. The process is characterized by extensive information provision regarding the new rights and responsibilities of water users through the future CMAs and by mobilization of ideas and buy-in for CMAs. Most is in the local language. The Local Governments are the key partners for discussion and expected to consult their constituencies and bring their views back to the plenary sessions. On the ground, local staff of DWAF, but also local staff of other government agencies are included in the process and play a complementary role in one-to-one interaction with poor communities for further information provision, problem diagnosis, and mediation in problem solving. The writing of the formal proposal, that is expected to take another year, is gradual and shared among several local 'task forces', supported by voluntary advisors from the areas.

Integrated water management through CMAs is not only crystallizing at basin level, but also at local level. On the ground, DWAF's service delivery is further integrated. Local DWAF staff improves its services, first, by better coordinating DWAF's internal departments such as Water Services, Groundwater, or Water Quality, and, second, promoting cooperative governance with other line departments. Costs and time are saved and goodwill gained by attending local events rather than calling special meetings. As DWAF staff's evolving relationships with communities are long-term, there is no problem of lost momentum that characterized the first approach.

5. DISCUSSION AND CONCLUSIONS

In all three modes of CMA establishment, water users from poor communities discussed for the first time in history about water resources management in their basin, directly with DWAF. People were keenly interested. Although such discussions were still relatively few, if not very few, they brought new needs and challenges to the surface.

In integrated water resources management in poor rural communities, a primary need is water development for livelihoods (Shah et al. 2001). *Developmental* CMAs are required that stimulate poor people's water use, not only for drinking water purposes, but also for productive purposes in farming, livestock, forestry, fisheries, and small-scale industries in order to combat income poverty. Conforming to hydrological reality in rural areas, an integrated approach is needed. Integration will also allow addressing inequities *within* communities between the poor and non-poor and men and women. Addressing intra-community competition for water requires a better understanding of customary water tenure and conflict resolution arrangements over water quantity and quality, which is a field of growing attention within DWAF.

The current formation of new integrated water management institutions offers new opportunities to design cooperative governance and integrated service delivery directed at the poor from the start onwards. Developmental CMAs could effectively stimulate networking and exchange for more productive water use from local to basin level, linked to other line agencies, the Local Governments, and NGOs. These links can be integrated parts of the future CMA proposals and catchment strategies.

A second new issue that emerged from these public consultations regards the competition over water between high-volume water users and poor water users. This may also be the underlying cause of intra-community water scarcity and conflicts. The reported cases underline how deeply disempowered the poor are vis-à-vis high-volume users in this regard. Such conflicts can only be mitigated, and possibly solved, through a skillfully facilitated process of dispute resolution. DWAF, in collaboration with NGOs and community-based organizations, can contribute to such process by information provision, legal literacy campaigns, and enhancing negotiation skills of all parties. The National Water Act and especially the tool of compulsory licensing will provide the necessary legal backing in such conflict resolution. DWAF staff is now being trained for such new tasks. Accumulating experience will generate a growing body of knowledge and skills in pro-poor water conflict resolution.

Third, with regard to the former, well-organized riparian titleholders, it is true that the past processes of establishing CMAs have been disappointing for them. Their hope to continue *de facto* control over water in the new public space offered through CMAs, which was certainly an important reason to endorse the National Water Act, is at least partly vanishing. An effective regulatory role by DWAF and the future CMAs vis-à-vis these high-volume water users in terms of restricted water allocation, demand management, and pollution prevention is crucial to contribute to poverty eradication. Licensing of any new water use by high-volume users, including the possibility to issue licenses on the condition that benefits are better shared with the poor, will remain a government task for many years ahead. In the water pricing strategy, over-use of water may be taxed and mechanisms for cross-subsidization to, for example, poverty programs be designed. While high-volume users may still expand self-governance, DWAF avoids a situation in which the vested powers 'pick the cherries' of the more rewarding functions in water management, leaving the problematic tasks to DWAF.

In short, the past experiences in establishing CMAs made clear that water management is never 'neutral', 'technical', or 'an end in itself'. Neither do neutral water institutions exist, whether they are

Catchment Management Agencies, Catchment Management Committees, Water Users Associations, forums, or Stakeholder Reference Groups. Nor is DWAF a neutral facilitator for institution building, limiting its role to that of a constitutional watchdog to ensure demographic representation. Decentralizing water management is even less handing-over neutral authority from the state to a neutral public.

Instead, decentralizing integrated water management that contributes to poverty eradication requires careful design and implementation of new pro-poor water institutions from local to basin level. DWAF's action is key to the success. One task is leveling the playing field in the public participation processes for these new institutions, by pro-actively reaching out to many more poor communities, providing information and legal literacy in local languages via multiple media, capacity building, ensuring mobility, structuring and enabling effective representation, and last but not least by mediating in conflicts. DWAF is also the key player in reallocating water and redressing inequities and in enforcing water saving and pollution prevention among high-volume users. Lastly, it largely depends upon DWAF, together with other rural development agencies, how fast water will be further developed to contribute to poor people's health, incomes, and decision-making power, in order to realize 'Enough for All Forever'.

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Re-engineering of interlocking log frames - An irrigation project design case

E. Alaphia WRIGHT

Faculty of Engineering, University of Zimbabwe, P.O. Box MP 167,
Mt. Pleasant, HARARE, Zimbabwe

alwright@africaonline.co.zw

ABSTRACT

The popularity of the Logical Framework Matrix (Log Frame) for summarising the design of policies, strategies, projects and programmes has been increasing in the last several years. This rapid spread of the use of the log frame has been accompanied by confusion associated with interlocking log frames depicting the linkages between programmes and their constituent projects. It has become increasingly evident that clarification of this issue is necessary. This paper briefly examines and discusses the types of interlocking log frames in use in practice. It is based on the author's research findings and experience in working with hundreds of log frames covering the views of stakeholders in various programmes and projects. It is shown that basically two types of interlocking log frames are in use: interlocking log frames type-1, and interlocking log frames type-2. The former, with its multiple overall goals is quite complex. It is known to lead to confusion, not only with the designs, but also with roles and responsibilities during implementation of programmes and projects based on it. The latter employs one overall goal (or explicit customisations of the same) for a programme as well as for the constituent projects. The two types of interlocking log frames are illustrated with the help of the design of an irrigation project. It is concluded that in working with interlocking log frames, the simpler type-2 model will give unique project details, and its use is therefore to be preferred.

Keywords: *Logical Framework Approach; Interlocking Log Frames; Type-1 model; Type-2 model; common vision or overall goal; multiple goals; sub-optimisation; programmes; projects; policies*

INTRODUCTION

The Logical Framework Matrix (Log Frame) is being increasingly used to summarise the design of policies, strategies, programmes and projects for organisational development and strategic planning in both the public and private sectors. In particular, several bi-lateral and multi-lateral organizations have actually made the use of the log frame mandatory in the compilation of project and programme documents. The popularity of the log frame is due primarily to its well-structured form and inherent logic. It has proved to be an invaluable communication tool for sharing programme and project details with diverse stakeholders.

Not surprising, the rapid spread of the log frame has been accompanied by some difficulties. Prime among these is the confusion with interlocking log frames depicting the linkages between programmes and their constituent projects. It has become increasingly evident that clarification of this issue is necessary. The aim of this paper is therefore to briefly examine and discuss the types of interlocking log frames in use in practice. It is based on the author's research findings and experience in working with hundreds of log frames covering the views of stakeholders in various programmes and projects. It builds on an earlier paper, which emphasised the systems aspects of the log frame (Wright, 2000).

Fundamentally, to engineer something is to 'make it' or, more appropriately, to 'build it'. By this token, re-engineering implies to re-build, but generally with the overall objective of improved performance, be it for a better product or for a better service. This paper covers the re-engineering of interlocking log frames. The presentation is in three main sections. The first section re-visits some basics of the log frame. The second section discusses the approach in which the purpose in the programme's log frame translates to the overall goal(s) of the constituent projects. The third section examines the simpler and unique situation in which a programme and its constituent projects have the same overall goal - the common vision. Some concluding remarks are offered at the end.

1: SECTION 1: BASICS OF THE LOG FRAME RE-VISITED

Several publications provide useful information on the log frame and its use. (GTZ, 1988 & 1995; NORAD, 1992; EC, 1993; Jackson, 1997; Wright, 1998 & 2000). Formally, the log frame will normally give details such as:

What benefits are expected from a project (Overall Goal)?
What changes or actions are expected from the project's target groups (Purpose)?
What deliverables are necessary for the success of the project (Products/ Outputs/ Enabling Conditions)?
What has to be done in order to deliver outputs (Activities)?
What external factors may influence project outcome (Important Assumptions)?
What will be used to measure the performance of the project (Performance Indicators/Achievements)?
What are the sources of data on the indicators (Sources of Verification), and
What the project will cost (Inputs and Costs).

Figure 1 shows a sketch of the log frame. From a systems perspective, ALL the key players in a given programme or project situation can be categorised into three main groups:

- The project interventionists or activists responsible for delivering outputs or enabling conditions (Activities and Outputs);
- The target groups or beneficiaries of the project (Purpose and Overall Goal), and
- Important third parties (who are not activists or target groups) but whose actions can have make or break consequences for a project or programme (Important assumptions or External Conditions).

The three groups must work in a complementary manner, in order for the project to be successful. Further, the entries in the first column of the log frame exhibit a series of means-end relationships: Activities (= means) lead to outputs (= end); Outputs (= means) lead to purpose (=end), and Purpose (=means) leads to overall goal (end).

There are, of course, several implementations of the log frame. A common implementation in use combines the indicators-column and the sources-of-verification-column into the 'inputs and costs' column for the activities. The sketch in Figure 1 shows an implementation, which makes provision for milestones and responsible parties to be given for the various major activities in addition to specifying the inputs and costs, (UZ, 1998). Also, the terms used to describe the various levels of objectives vary somewhat among the different implementations. Hence, the following terms (among others) are usually met with for the various levels of objectives:

Highest level of objective:

- Overall goal;
- Overall Objective;
- Long term Objective;
- Vision.

2nd highest level of objective:

- Purpose;

- Intermediate objective;
- Mission;
- Outcome;
- Results.

3rd highest level of objective
- Results;
- Outputs;
- Immediate objectives;
- Deliverables;
- Products;
- Enabling Conditions.

Activities (4th highest level of objective)
- Activities;
- Tasks;
- Actions;
- Processes.

	Summary of Objectives and Activities	Performance Indicators	Sources of Verification	External Conditions
Overall Goal (Vision)				
Purpose (Mission)				
Outputs / Enabling Conditions				
		Milestones	**Leader or Initiator**	**External Conditions**
Major Activities				
Inputs and Costs				**Pre-Conditions**

Figure 1: The Logical Framework Matrix (LFM) or Log Frame.

Further, the headings for columns 2, 3 and 4 in Figure 1 can also take different names in some implementations, namely:
Column 2:
- Objectively verifiable indicators;

- Performance indicators;
- Targets;
- Achievements.
-

Column 3:
- Means of verification;
- Sources of verification.

Column 4:
- Important Assumptions;
- External Factors;
- External Conditions.

For the purpose of this paper, the terms given in Figure 1 will be used throughout.

2: SECTION 2: PROGRAMME PURPOSE TRANSLATES TO PROJECT'S OVERALL GOAL (Interlocking Log Frames Type-1)

The approach in which the programme purpose is translated to the overall goal(s) of the constituent projects can best be illustrated with the sketch shown in Figure 2, for a programme having two constituent projects.

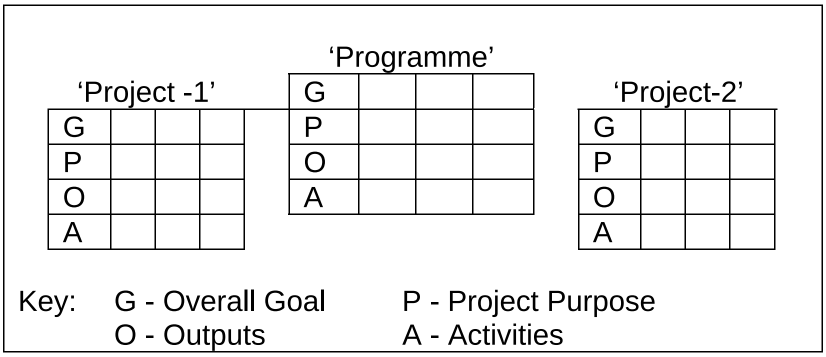

Figure 2: Interlocking Log frames Type-1 with multiple overall goals

The fundamental idea here is that for the individual projects to logically fit into the overall programme, their respective goals should explicitly depict the programme purpose (NORAD, EC). In the same light, the programme outputs can be translated to the purposes of the projects while the programme activities become outputs of the projects. In a sense the links between the programme and its constituents projects is characterised by a 'downward cascading' arrangement as shown in Figure 3. Table 1 shows some example entries from the first columns of a programme and a project using interlocking log frames type-1 (EC, 1993).

2-1: Characteristics of Interlocking Log Frames Type-1

A closer look at Table 1 will reveal that the programme's output; 'increased rice production' is taken over as the project purpose for the rice project. Further, the rice project would have an irrigation component (sub-project) with the overall goal 'increased rice production', and the project purpose ' functioning irrigation network'. In a similar manner there would be a project on 'improved storage and distribution' for which components can also be specified. Clearly, the log frames of the programme, projects and components are indeed interlocking. Using interlocking log frames type-1 immediately results in multiple overall goals, one each for the constituent projects and the programme in question.

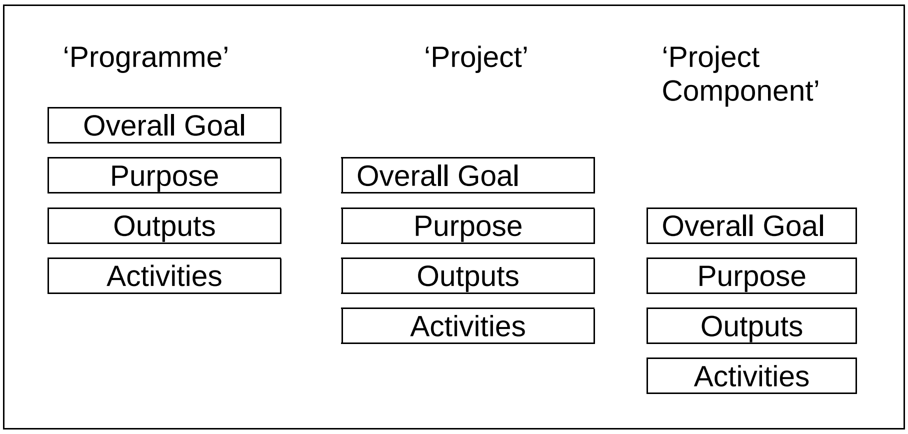

Figure 3: Interlocking Log frames Type-1; Downwards cascading arrangement

Logically, using Table 1 as an example, output-1 of the food programme, 'increased rice production', is achieved with the accomplishment of the project purpose of the rice project. Further, we see the same expression, 'increased rice production' appearing as an output of the programme, a project purpose of the rice project and the overall goal of the irrigation sub-project. This in itself is usually a major source of confusion for stakeholders of programmes and their constituent projects.

Table 1: Example entries for interlocking log frames type-1 model. Adapted from PCM Manual (EC, 1993).

Food Programme	Rice Project	Component of Rice Project (Irrigation)
Overall Goal: Improved standard of living		
Project Purpose: Improved food situation	**Overall Goal:** Improved food situation	
Outputs: 1: Increased rice production 2: Improved storage and distribution 3: etc.	**Project Purpose:** 1: Increased rice production	**Overall Goal:** 1: Increased rice production
Activities: 1-1: Repair irrigation system 1-2: Ensure supply of inputs, etc.	**Outputs:** 1-1: Functioning irrigation network 1-2: More regular supply of inputs, etc.	**1-1: Project Purpose:** Functioning irrigation network
	Activities: 1-1-1: Organise farmers 1-1-2: Dig channels 1-1-3: etc.	**Outputs:** 1-1-1: Channels dug 1-1-2: Dykes raised 1-1-3: etc.
		Activities: 1-1-1-1: supervise digging of channels 1-1-1-2: Supervise raising of dykes 1-1-1-3: etc.

There are several reasons for this. In the first place, the definition of the overall goal in the case of interlocking log frames type-1 appears to vary from programme to projects to components. This is fundamentally contradictory. The overall goal should clearly be the 'highest attainable and measurable objective', indicating 'benefits' in the given situation. In this case the food programme.

Also, by definition, the purpose should depict target group's action, the outputs depict deliverables from project interventionists, and activities spell out the actions necessary for producing the outputs. In employing interlocking log frames type-1, these definitions are inherently changed back and forth, thus resulting in multiple log frames and instances of complex overlapping of details. This leads to difficulties, not only with the designs of the programmes and projects themselves, but also with roles and responsibilities in managing them.

To illustrate this issue further, refer to Table 2. Table 2 is the first two columns of Table 1 with a third column added, and referred to as the revised rice project. Now, considering the systems characteristics of programmes and projects, and for that matter, the log frame, (Wright, 2000), if we ask the question: 'who increases rice production?' we get the answer: 'the farmers'. 'Increased rice production' clearly constitutes 'outputs' of the farmers.

Table 2: Revised rice project from Table 1

Food Programme	Rice Project	Revised Rice Project
Overall Goal: Improved standard of living		**Overall Goal:** Improved standard of living
Project Purpose: Improved food situation	**Overall Goal:** Improved food (rice) situation	**Project Purpose:** Improved food (rice) situation
Outputs: 1: Increased rice production 2: Improved storage and distribution 3: etc.	**Project Purpose:** 1: Increased rice production	**Outputs:** 1: Increased rice production 2: Sufficient water for irrigation available 3: etc.
Activities: 1-1: Repair irrigation system 1-2: Supply inputs 1-3: etc.	**Outputs:** 1-1: Functioning irrigation network 1-2: More regular inputs 1-3: etc.	**Activities:** 1-1-1: Plant increase acreage of rice 1-1-2: Operate irrigation 1-1-3: etc
	Activities: 1-1-1: Organise farmers 1-1-2: Dig channels 1-1-3: etc.	

Now, if we apply the means-end logic to the processes for the farmers, we end up with the entries shown in the third column of Table 2, where the overall goal of the rice project, 'improved food (rice) situation' has been replaced by the project purpose of the revised project, 'improved rice situation'.

As can be seen from the entries for the revised rice project (Table 2), expanding on the processes of the farmers on the basis of the fundamental definition of activities, outputs, purpose and overall goal, the constituent project details can, in fact, be specified to be at the same levels of objectives as the programme. In effect, the project purpose of the revised rice project would remain at the same level as that of the food programme. This is of course contradictory to the downward cascading arrangement implied with interlocking log frames type-1.

2-1-1: Advantages of Interlocking Log Frames Type-1

Two main advantages are associated with interlocking log frames type-1:

- It is the first widely used approach for relating programmes to their constituent projects and vice versa.
- In the hands of a highly skilled project planner or project/programme manager, the downward cascading interlocking arrangement can actually be advantageous in keeping track of the details of the various projects. This is similar to the practice of using Work Breakdown Structures (WBS) or Project Breakdown Structures (PBS) (Wright, 1998).

2-1-2: Disadvantages of Interlocking Log Frames Type-1

As far as disadvantages are concerned, three major aspects can be recognised:

- The practice of having the same element referred to as 'overall goal', 'project purpose' and 'output', depending on whether one is dealing with the programme or its constituent projects has been known to cause confusion;
- Most importantly, the use of multiple overall goals (or visions) - the absence of a common vision, implies that stakeholders of programmes and projects might very well not have a focused objective to work towards. They might very well not be 'pulling together'. By there very nature, multiple overall goals (visions) easily lead to sub-optimisation or its accompanying 'do-nothing' situation. As one implementer puts it: "You really don't know whether you are going or coming. One day you are talking to the sponsor, and he is asking you for your outputs. The next day he tells you that what you claimed to be outputs are really your processes or activities";
- The interlocking log frames type-1 model cannot guarantee unique representations of the levels of objectives between a programme and its constituent projects.

3: SECTION 3: PROGRAMME OVERALL GOAL AND THOSE OF THE CONSTITUENT PROJECTS ARE THE SAME (Interlocking Log Frames Type-2)

The second approach with interlocking log frames is one in which a programme and its constituent projects have one and the same overall goal. This is depicted in the sketch in Figure 4, for a programme with two constituent projects. The programme's log frame gives the overall design reflecting the various programme elements. The log frames of the individual projects are then nothing more than customisations of the programme log frame. With this approach there are no downward cascading arrangement, since the programme and the constituent projects will have the same overall goal, the common vision (Figure 5).

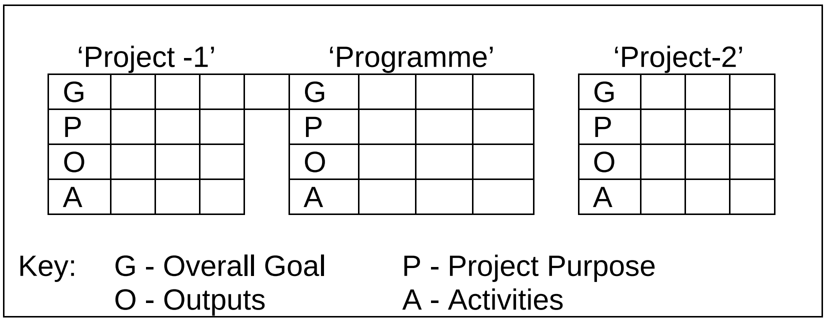

Figure 4: Interlocking Log Frames Type-2 with common overall goals

Table 3 shows an example of the use of the interlocking log frames type-2 for a reformulation of the food programme given in Table 1.

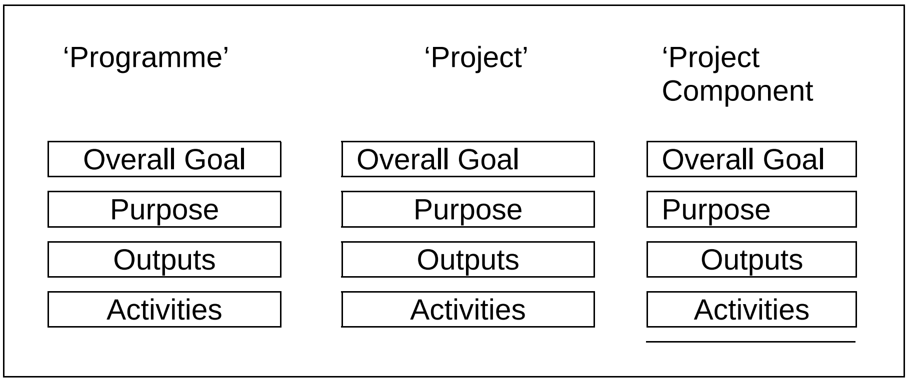

Figure 5: Interlocking Log Frames Type-2; without downward cascading arrangement

Table 3: Example entries for interlocking log frames type-2 for the food programme - irrigation

Food Programme	Rice Project	Component of Rice Project (Irrigation)
Overall Goal: Improved standard of living (e.g. in terms of the 'benefits' of having adequate FOOD, etc.)	**Overall Goal:** Improved standard of living (e.g. in terms of the 'benefits' of having adequate RICE, etc.)	**Overall Goal:** Improved standard of living (e.g. the 'benefits' of having adequate food (rice from IRRIGATION schemes, etc.)
Project Purpose: Improved food situation (Farmers produce more FOOD)	**Project Purpose:** Improved food situation (e.g. Farmers produce more RICE)	**Project Purpose:** Improved food situation (e.g. Farmers produce more rice from IRRIGATION schemes)
Outputs: 1: Effective and efficient procedures for FOOD production in place (e.g. which food to be grown where, etc.) 2: Suitable infrastructure for FOOD production in place and operational (e.g. irrigation facilities, etc.) 3: Farmers and other important players in the FOOD sector adequately trained 4: The FOOD programme is efficiently and effectively managed	**Outputs:** 1: Effective and efficient procedures for RICE production in place (e.g. where to grow which variety, etc.) 2: Suitable infrastructure for RICE production in place and operational (e.g. irrigation facilities, etc.) 3: Farmers and other important players in the RICE sector adequately trained 4: The RICE project is efficiently and effectively managed	**Outputs:** 1: Effective and efficient procedures for operating IRRIGATION schemes in place and their use actively promoted 2: Suitable and functional IRRIGATION infrastructure in place (e.g. water pumps, pipes, etc.) 3: Operators, maintenance personnel, etc. (for the IRRIGATION systems) adequately trained 4: The IRRIGATION project is efficiently and effectively managed
Activities: 1-1: Specify which FOOD crop is best grown in given regions 1-2: etc.	**Activities:** 1-1: Specify which RICE variety is best grown in given regions 1-2: etc.	**Activities:** 1-1: Specify which mode of IRRIGATION is best suited for given regions/conditions 1-2: etc.

3-1: Characteristics of Interlocking Log Frames Type-2

An important characteristic of the interlocking log frames type-2 is that each programme and constituent project is unique with its own activities, outputs, and purposes clearly contributing to the common overall goal. The fundamental definitions of overall goal, project purpose, outputs (or enabling conditions) and activities are preserved throughout. For instance, if we repeat the question: 'who produces more food (e.g. rice)?' The answer is clearly 'the farmer' (= farmers doing things differently for the better), which is by definition, the purpose! Recall that with the interlocking log frames type-1 approach the answer to this question would have been interpreted to mean outputs as shown in both columns 1 and 3 of Table 2. Interlocking log frames type-2 easily accommodates the practice of co-existing log frames for programmes and their constituent projects in a unique manner, with overlapping details only at the common overall goal levels. This leads to clearer roles and responsibilities.

3-1-1: Advantages of Interlocking Log Frames Type-2:

There are several advantages associated with interlocking log frames type-2:

- In the first place, the practice of having one overall goal (vision) is known to be a unifying element in many organizations and situations, since the chances of sub-optimisation are eliminated. This practice is, in fact, universally acknowledged;
- For a programme it could easily be seen that each of the constituent projects are, in fact, making their respective contributions to the achievement of the overall goal;
- The structure of the programme will invariably dictate the structure of the constituent projects, and this simplifies the design and management of the respective projects. The confusion normally associated with interlocking log frames type-1 is eliminated thus enhancing the chances for successful projects;
- Clearly, interlocking log frames type-2 model is simpler than the type-1 model.

3-1-2: Disadvantages of Interlocking Log Frames Type-2:

Possibly the most evident disadvantage of interlocking log frames type-2 is that it has not yet been widely disseminated as the type-1 model.

4: CONCLUSIONS

The two types of interlocking log frames in use in practice have been presented above. The presentation of the log frames has been restricted to extracts from the first column of the general log frame. As such, performance indicators, sources of verification, and external conditions have not been discussed.

Interlocking log frames type-1 employ multiple overall goals, with the programme purpose translating to the overall goals of the constituent projects. A major weakness with interlocking log frames type-1, is that fundamental contradictions can easily be constructed. Also, the resulting multiple log frames are characterised by complex overlapping details leading to confusion in roles and responsibilities in managing the projects involved.

Interlocking log frames type-2 are characterised by the programme and its constituent projects having one and the same overall goal. This is nothing but the universally accepted practice of working with a common vision. Interlocking log frames type-2 easily accommodates the practice of co-existing log frames for programmes and their constituent projects in a unique manner leading to clearer roles and responsibilities. Evidently interlocking log frames type-2 has a simpler structure.

Considering the aim of this paper, the following concluding remarks are offered:

- The interlocking log frames type-1 model, with its multiple overall goals is quite complex and is known to lead to confusion with its use;
- The interlocking log frames type-2 model, on the other hand, employs one overall goal (or explicit customisations of the same) for a programme as well as for the constituent projects;

- In working with interlocking log frames, the simpler type-2 model will give unique project details, and its use is therefore to be preferred.

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