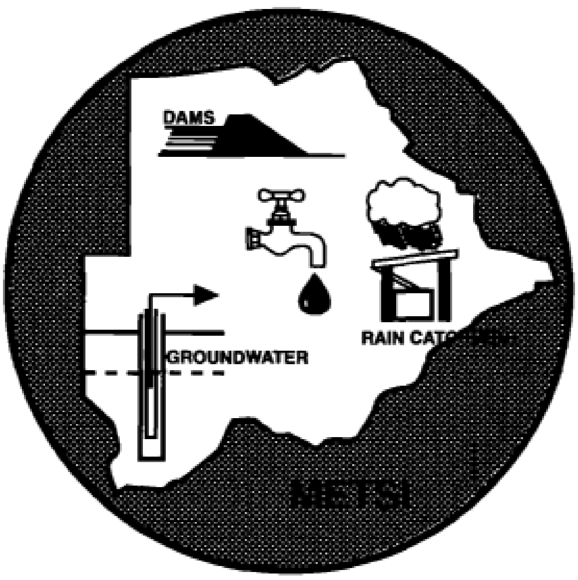
INTEGRATED WATER RESOURCES MANAGEMENT WORKSHOP 1994

PROCEEDINGS



17 - 18 March, Kanye - Gaborone

Edited by

A. Gieske and J. Gould

Hosted by the University of Botswana and the Rural Industries Innovation Centre and sponsored by the Swedish International Development Authority (SIDA)

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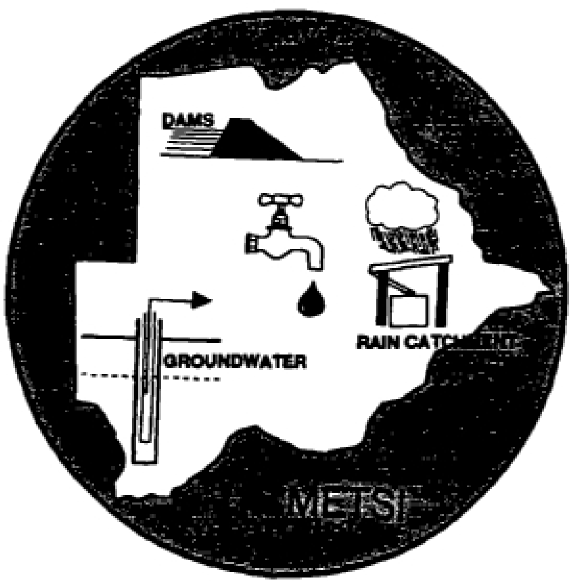

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INTEGRATED WATER RESOURCES MANAGEMENT

PREFACE

Water is a crucial resource affecting many aspects of the nation's development and natural environment. The National Conservation Strategy identifies it as a key resource in any plan for implementing a sustainable approach to development. It therefore seemed timely in the light of the recently completed National Water Master Plan to examine some of the issues involved and potential strategies available for bringing about a more integrated and sustainable approach to water resource management in Botswana.

The purpose of this workshop was therefore to provide a forum to discuss broad aspects of water resource management which relate to general long-term resource and environmental planning issues, such as for example soil and water conservation, environmental economics and water resources, conjunctive use of surface and ground water, and the problem of securing sustainability of water supplies in the future. It was hoped that discussions would also focus on issues relating to lands area water supplies and social aspects of water supply provision and how to best meet the needs of **all** Batswana including those living in remote locations.

The Workshop covered these aspects under three main themes

1. Sustainable Water Resource Management
2. Water Resource Development and the Environment
3. Appropriate Water Technologies

After the opening by Prof. J.S. Nkoma, Dean of the Faculty of Science at the University of Botswana, Mr Khupe, Director of the Department of Water Affairs provided the opening paper on *Integrated Water Resource Management in Botswana.* Our first keynote speaker from Sweden : Prof Malin Falkenmark from the University of Lindköping, a well respected international authority on Water Resources and the Environment put the issue in a broader context with her paper on *Successfully Coping With Complex Water Scarcity.* Our second keynote speaker Mr Jan Krook now working as a consultant and formerly attached to the Department of Water Affairs in Gaborone, completed the opening session with his paper entitled *An Overview of Water Resources Development in Botswana.*

The afternoon of the first day of the workshop involved a field excursion to Otse and Kanye during which a variety of water schemes were visited. The second day's proceedings were held at the Rural Industries Innovation Centre (RIIC) in Kanye and 17 short papers under the three main workshop themes were presented in the morning session. In the afternoon three group discussions took place, the output of which is included in these Workshop Proceedings.

ACKNOWLEDGMENTS

This workshop was organized jointly by the Departments of Geology and Environmental Science at the University of Botswana in co-operation with the Ministry of Mineral Resources and Water Affairs (MMRWA), the Ministry of Local Government, Lands and Housing, the Ministry of Agriculture and the Rural Industries Innovation Centre (RIIC) in Kanye. The assistance of these institutions and numerous individuals working in the water sector in Botswana who made this workshop possible are gratefully acknowledged.

Special thanks should also go to colleagues and to the Public Relations Office at the University of Botswana for assisting with practical arrangements for the opening session. Appreciation is also due to Ms N. Ncgongco and Ms G. Lesetedi for assisting with registration and acting as rapporteurs.

The workshop has been sponsored by the Swedish International Development Authority (SIDA) and their support is much appreciated.

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OPENING SPEECH

J.S. Nkoma, Dean, Faculty of Science
University of Botswana

Mr. Chairman,
Distinguished Guests,
Ladies and Gentlemen!

I am most grateful and extremely delighted to deliver an opening address to this **Integrated Water Resources Management Workshop**, which is being hosted at the University of Botswana and the Rural Industries Innovation centre, Kanye, with today's session being held here at UB and tomorrow at RIIC. Two of our Departments in the Faculty of Science, the Department of Environmental Sciences and the Department of Geology, have participated in the organisation of this workshop together with the Ministry of Mineral Resources and Water Affairs (MMRWA), the Ministry of Local Government, Lands and Housing, the Ministry of Agriculture and the Rural Industries Innovation Centre (RIIC).

Water is a finite and scarce resource that is vital to many aspects of national development. It is also a non-substitutable resource. In spite of developments in science and technology, there is as yet no way we can meet the water demands artificially! If there is no water, people can not survive.

That this workshop should be held now is timely, especially in light of the recently completed Botswana National Water Master Plan (BNWMP) which includes an exhaustive analysis of water management in Botswana over the thirty year period, 1990 - 2020.

Mr. Chairman, this workshop provides a forum to discuss several aspects of water resource management. In particular, the workshop is expected to cover three themes:

1. **Sustainable water resource management**, where five papers will be presented.
2. **Water resources development** and the environment, here also with five papers to stimulate discussions.
3. **Appropriate water technologies**, where seven papers are to be considered and discussed.

Several topics will be addressed, such as urban and rural water supplies, water demand projections, ground water level monitoring, social aspects related to water supply systems, protection of water from pollution, the role of Environmental Impact assessment in water resources, water treatment and purification, some hydrological characteristics and design criteria for construction of small dams etc.

On behalf of the Faculty of Science of the University of Botswana, and on my own behalf, I welcome you, and wish you successful deliberations. May you come out with insights and suggestions that will encourage sustainable integrated water resource management in Botswana. Thank you!

INTEGRATED WATER RESOURCE MANAGEMENT IN BOTSWANA
OPENING ADDRESS WORKSHOP, 18-19 MARCH, GABORONE

B. B. Khupe, Department of Water Affairs, P/Bag 0029, Gaborone

INTRODUCTION

In a semi-arid country such as Botswana and drought prone region like the Southern Africa the conservation and careful management of the water resources is a matter of necessity and great importance. Hence the focus on water resources management and in particular integrated management has become critical over the past few years. Competition for limited or diminishing water resources by different users in the country and also in the region as a whole is increasing and is exacerbated by the erratic rains and impredictable climatic conditions resulting in frequent severe droughts as recently experienced in Southern Africa.

Man made changes to water resources systems resulting from poor management of both surface and ground water can have large and sometimes irreversible adverse environmental impact.

What is Water Resources Management?.

The overall concept of Water Resources Management (WRM) can be considered under three activities distinguished as:

(i) Water Resources Development (WRD)
(ii) Water Resources Planning (WRP)
(iii) Water Resources Management (WRM)

The detailed definitions of these activities will be dealt with in detail during this workshop but the broad definitions can be given as follows:-

Water Resources Development: Physical activities to improve the beneficial use of water for water supply, irrigation, flood alleviation, energy production, water based recreation, fisheries etc.

This definition WRD has different meaning to people from different backgrounds as indicated in Figure 1.

Water Resources Planning: Planning of the development and allocation of a scarce resource (sectoral and intersectoral), matching water availability and demand, taking into account interests of stakeholders. Hence WRP is and should be multi-sectoral, multi-objective and multi-constrained.

Water Resources Management: The whole set of technical, institutional, managerial, legal and operational activities required to plan, develop, operate, and manage water resources.

What is Water Resources Development ?

- **to people in arid countries :**
  - drought relief
  - irrigation
  - jobs, food
  - flash floods

- **to people in wet countries :**
  - water works
  - navigation
  - flood protection
  - hydro power

- **to the water engineer :**
  - dams, reservoirs
  - flood protection
  - river training
  - water treatment

- **to the environmentalist :**
  - habitat deterioration
  - deforestation
  - pollution
  - destruction of wet lands

- **to the lawyer :**
  - legislation
  - international law
  - water rights

- **to the economist :**
  - stimulation of economic growth
  - poverty alleviation
  - employment generation

Fig. 1 How do people from different backgrounds consider Water Resources Development.

This is a process including all activities of planning, design, construction and operation of water resources systems. Hence WRM is by definition integrating all aspects and functions related to water which leads us to the theme topic of this workshop, "Integrated Water Resources Management".

It is not my assignment here to define what Integrated Water Resources Management is but this workshop's task.

I would like now to shortly address myself to the water resources management with respect to Botswana.

BACKGROUND

Botswana is a semi-arid, landlocked country covering an area of about 582 000 km^2 between latitudes 18° S and 27° S in the centre of Southern Africa.

The population is estimated at slightly above 1.3 million (by 1991 census) and fast growing at rate of 3.4% per annum. At this rate the population will double within the next 30 years, with about 30% or more of the people staying in urban areas as compared to 20% now.

The country has a fast growing economy based mainly on mining and livestock for its foreign exchange earning. This fast economic growth coupled with increase in population, is putting more stress on its scarce water resources.

WATER RESOURCES

Water is a vital resource to Botswana's economic development, but it is scarce and costly to develop. Most of the water originates from rainfall which is erratic and unreliable. The long-term mean annual rainfall varies from minimum 250 mm in South-West to a maximum of 650 mm in the extreme north.

This gives an average of about 450 mm per annum overall against an estimated annual evaporation of 2000 mm. Most of the rivers are in the eastern part of the country and are ephemeral. The only perennial systems are the Chobe and Okavango rivers in a less densely populated area in the north-west and north. These two rivers constitute about 95% of the total surface water. The ephemeral systems have an estimated yield of 1200 million cubic meters per year of which about 19% is already stored in man made reservoirs.

The groundwater on which about 80% of the population and livestock depends, has an estimated extractable volume of 100 000 million cubic meters, but only 1% of this is rechargable by rainfall.

The depths of the boreholes range from 30m to 600m and the quality also varies from east to west where saline water is found. Water reuse is another potential source in which could be developed particularly as demands increase. The estimated return flows from urban areas are 10.5 Mm^3/year (1990) growing to 64.4 Mm^3 in 2020.

WATER DEMAND

The water demand is divided among settlement, mining, energy, agriculture and wildlife.

The settlements component comprises of domestic, commercial, industrial and institutional, while agriculture is split into livestock, irrigation and forestry. The total demand also includes distribution and treatment losses.

The present total demand is estimated at about 120 million cubic meters per annum, and the demand will almost triple to 336 million cubic metres per year by year 2020. This is a huge increase and will outweigh the presently available water resources.

The demand per consumer now and by 2020 is as shown in the table below :-

Table 1 Water demand projections in the different sectors.

Consumer	Demand in m^3/year 1990	2020
Urban Centres	21 (17.7)	103 (30.7)
Major Village	8 (6.7)	52 (15.5)
Rural Settlements	7 (5.9)	20 (5.9)
Mining and Energy	23 (19.3)	64 (19.0)
Irrigation	19 (16.0)	47 (14.0)
Livestock	35 (29.4)	44 (13.1)
Wildlife	6 (5.0)	6 (1.8)
	119	336

Note: Figures in brackets are percentages.

The table above shows that at present livestock (estimated at 3 million) consumes most water, followed by mining and energy. This trend will change by year 2020 when urban centres will consume most water followed again by mining and energy.

Therefore in relative terms livestock water demand will decrease, as it is expected that the number of livestock will not increase significantly due to droughts.

Irrigation requires a lot of water, on average estimated at 15 000 m^3 per ha. per year. But the demand for irrigation is not expected to grow very fast because due to shortage of water and good soils the Government of Botswana has abandoned the food self sufficiency and adopted the food security approach.

When compared to other countries in the world Botswana's annual water consumption at approximately 92 m^3 per person is still one of the lowest (see Figure 2 below).

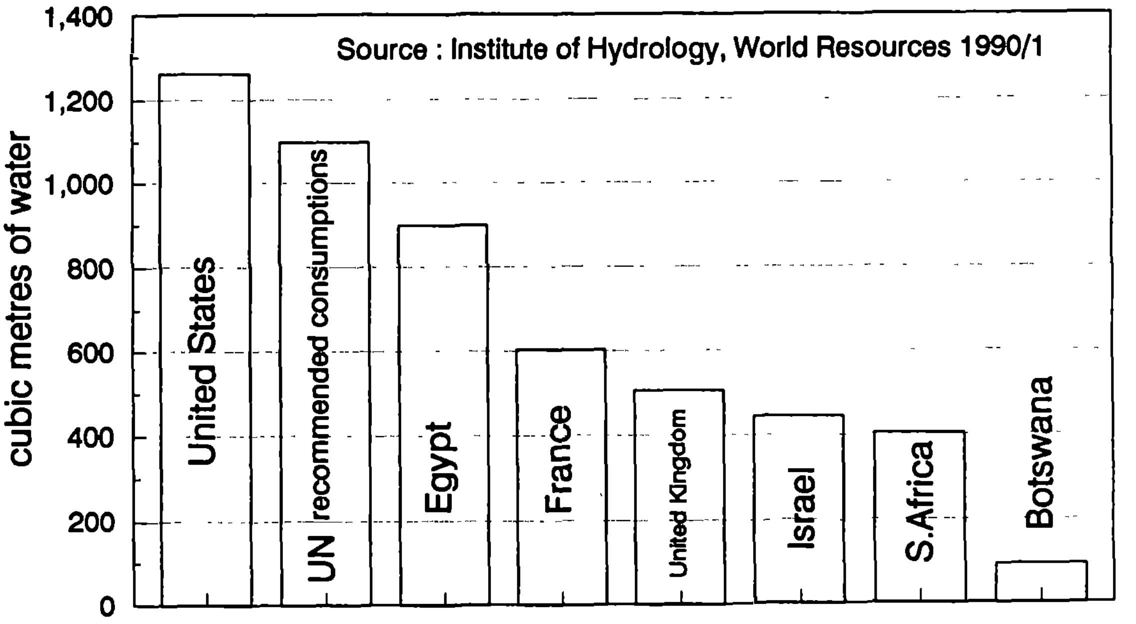

Fig. 2 Graph showing the average annual consumption per person of water (in cubic metres) for a number of countries.

INSTITUTIONAL FRAMEWORK

Responsibility for water in Botswana is at present shared between a number of Ministries, Departments, Parastatals and other bodies. This reflects the way in which the country has developed over the years since gaining Independence during which the institutions and laws that created them have been adopted to meet the changing needs and circumstances.

The institutional framework for water normally varies from country to country. In Botswana, the Ministry of Mineral Resources and Water Affairs is responsible for policy formulation, planning, development and management of water and mineral resources. Its portfolio of responsibilities relating directly to water are discharged through the Department of Water Affairs, Department of Geological Surveys and a parastatal, the Water Utilities Corporation.

The Department of Water Affairs is responsible for overall water resources planning, investigation, design and construction including operation and maintenance of 17 major village water supplies. The department also designs and constructs rural village water schemes which on completion are handed over to the respective district councils for their operation and maintenance. The Director of Water Affairs is also the Registrar of the Water Apportionment Board which is a quasi-judicial body with important powers and duties to record, grant, refuse, vary or terminate water rights under the Water Act 1968) and for administration, in so far as it affects the water rights, of the Aquatic Weeds Control Act.

Responsible for the overall assessment of the groundwater resources, the Department of Geological Surveys interfaces on a broad front with Department of Water Affairs. The Department maintains the National Borehole Archive, which provides a database for the assessment of groundwater potential throughout the country and is charged with the administration of the Borehole Act 1956, which requires those sinking boreholes or carrying out related operations to furnish information and records to the "Director".

The Water Utilities Corporation was established in June 1970 (by the Corporation Act Cap 74:02 - Laws of Botswana) with the intention that its activities should be restricted to the urban areas where public water supply services could be financially self supporting.

The Act regulates the commercially aligned principles of financial operations to be followed. The Corporation's activities are governed by the Waterworks Act which requires, inter alia, that its tariffs be subject to Ministerial approval.

LEGAL FRAMEWORK

All water in Botswana belongs to the state, whatever its source. The main body of laws in Botswana directly concerned with water comprises four Acts some of which have been were subsequently modified by short amending Acts. These are:

(a) Water Act 1968 Cap 34:01
(b) Borehole Act 1956 Cap 34:02
(c) Waterworks Act 1962 34:03
Waterworks Amendment Act 1983 (16/83)
(d) Water Utilities Corporation Act 1970 Cap 74:02
(WUC Amendment Act 1978 (3/78)

Besides these there are other Acts which have bearing on water, though some only marginally. The Public Health Act, for instance, gives environmental health officers power to ensure the purity of public water supplies, Local Government District Councils Act enables the district councils to provide water supplies outside any area for which a water authority has been appointed under the Waterworks Act, Aquatic Weeds Control

Act which prohibits importation or transportation of undesirable aquatic weeds into the country or from one body of water to another without permit. The provisions of the principal Acts are summarised below :-

The Water Act 1968 is the basic statute and contains what might be termed the "common law" aspects of water: the status of public water; the inherent rights of individuals to the use of water; the recording, granting, variation and termination of formal rights to use or impound water or to discharge effluents into it; the obligations of those taking water to use it properly and conditions controlling pollution of public water and so on. This Act established the Water Apportionment Board as the Licensing Authority and prescribed its constitution, powers and duties. The Board Secretariat is provided by the Department of Water Affairs.

The Boreholes Act 1956 is a short statute which stipulates the records and samples which have to be kept and furnished to the Director of the Department of Geological Surveys by any one sinking a deep borehole, that is more than 15 m below the surface or deepening of an existing borehole.

Contractors engaged in drilling operations on behalf of clients are required to comply with the provisions of the Act.

The Waterworks Act 1962 and its short amendment provide for constitution of water authorities in township and other areas designated by the "Minister" and confers powers and duties upon them. Included among these are: the right to acquire existing waterworks; to construct new works; to curtail supplies in time of drought and other emergencies, etc. It also deals with the charges for water supplied; supplies to non-statutory areas and the misuse and pollution of water. Further, it authorises the "Minister" to make regulations on such matters as prevention of waste, suspension of supplies, and the inspection and testing of meters and other appurtenances.

The Water Utilities Corporation Act 1970 which established the Water Utilities Corporation for the supply and distribution of water within the Shashe Development Area and elsewhere and conferred the necessary powers to develop water resources. The Act is specific on the Construction of the Corporation; the appointment of members; procedures; powers of acquisition of works and other matters. The financial principles and methods of charging for water which it must observe are also specified. The Act further provides that the Corporation shall be the "Water Authority" for the purpose of the Waterworks Act so that all the provisions of the latter Act apply to it.

LONG-TERM WATER RESOURCES DEVELOPMENT PLAN
(National Water Master Plan)

Water is a scarce resource both in Botswana, and as the recent droughts indeed demonstrated in the whole Southern Africa region.

Therefore more coordination and careful planning at national and regional level is required in order to meet the ever increasing water demands.

This need for careful planning of the water resources development is influenced by a number of factors such as:

a) the very flat terrain which results in very few suitable dam sites.

b) the high rates of evaporation, the effects of which are exacerbated because of the unfavourable storage sites which usually have a low ratio of volume of water stored to surface area leading to shallow reservoirs of wide expanse,

c) the high temporal variability of runoff which requires surface water storages to be large in relation to the mean annual runoff in order to provide carry-over storage for drought,

d) the difficulties of assessing the hydrologic characteristics of catchments in a semi-arid environment where the potential evapotranspiration is about four times greater than the rainfall and where the available streamflow records are relatively short.

e) recurrent droughts which affect both the inflow into dams and recharge to groundwater.

f) environmental considerations in terms of the impacts of water resources development and the mining of the groundwater. Because of the arid nature of the country most of the ecosystems are already naturally at a critical balance and therefore negative impacts of water resources development can potentially be disastrous.

The above factors make water resources development in Botswana very expensive.

To ensure that Botswana's water resources are developed in a sustainable way, maximising limited resources for the benefit of the nation and future generations, the Government is developing a National Water Master Plan.

The National Water Master Plan (NWMP) is based on an exhaustive analysis of alternative options for the development of Botswana's water resources to meet the water requirements of all sectors of the community over a period of thirty years (1990-2020).

The plans not only outline the basic physical and engineering developments needed, but also take into consideration environmental, economic, social, institutional and legal factors.

Under the NWMP, all Botswana's water demands are carefully balanced against the resources available to meet them, while solutions to the problem of growing demand are determined by evaluating the environmental and economic ramifications of a variety of options including, different combinations of surface water reservoirs and groundwater development.

With regards to water development and the environment in Botswana, the NWMP specifically recommends:-

- close monitoring of groundwater wellfields to avoid excessive depletion of these non-renewable water resources. In cases where the rate of extraction is greater than the rate of replenishment, alternative water resources must be found;

- greater use of alternative technologies to develop and conserve water sources; e.g. desalination

- more recycling of existing water supplies;

- encouraging management and the development of water supplies by local communities.

- greater co-ordination between Government institutions in the planning and development of water resources;

- inclusion of Environmental Impact Statements (EIS) as an integral part of all project feasibility and subsequent studies for water development projects.

Meeting Botswana's Water Needs

The needs of the heavily populated eastern region of Botswana can be met up to year 2020 by a two-phase dam project in the North east of the country. Needs thereafter will probably be met from the Zambezi river system, which is shared with Angola, Namibia, Zambia, Zimbabwe and Mozambique and to less extent Malawi and Tanzania.

Unlike the Okavango river, which flows from Angola through the Caprivi strip in Namibia and ends on an inland delta, the Chobe River flows through the Zambezi into the Indian Ocean. The environmental consequences of abstraction from the Chobe are less problematical than from the Okavango river. Unfortunately, the Chobe is a long way from major population centres. Long term plans to carry water from it are being evaluated. Extraction from the Okavango Delta for long distance has been ruled out, but use for local communities is still open for further consideration.

The South-west of the country is historically sparsely populated. Government plans do not include any substantial development because water is so scarce. Desalination units are being installed so that the needs of existing communities there may be met from large reserves of salty water under the Kalahari desert.

The long-term implications of the NWMP are that due to scarcity of water resource the development of water-intensive agriculture and industry cannot be accommodated. Botswana has given up its plans for self-sufficiency in food because of lack of water, and has moved instead to a programme of food security in its 1991 Agriculture Policy. The Government will not, therefore be pursuing the 1100 cubic metres per capita per annum required for food self-sufficiency.

Botswana is committed to preserving its rivers and the country's greatest treasure, the Okavango. Its attitude to development which threatens these resources is that such development should not take place.

PRICING POLICY

The pricing policy for water in Botswana is based on principles of equity and affordability. That is those who can afford should pay the full cost price and those who cannot afford it do not pay for water consumed. There is no Government subsidy on water in urban areas, but those who use large quantities pay more to subsidize those who use less.

Water from communal standpipes is free in rural areas thus ensuring that everyone has access to safe drinking water. Those with private connections in rural areas who use only a minimal amount of domestic water pay a price which is lower than the cost of production. Those who use moderate quantities pay a price which is roughly equal to the production cost, whilst those using excessive quantities pay a heavy penalty for additional volume used above a set amount.

Both rural and urban tariffs are stepped-up with the former targeted to recovery full recurrent cost by 1996/97 while the latter is based on full cost recovery.

The result of this policy is that Botswana still uses only 92 m^3 per capita per annum, which is significantly lower than the UN. recommended figure of 1100 M^3 per capita/year.

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SUCCESSFULLY COPING WITH COMPLEX WATER SCARCITY - AN ISSUE OF LAND/WATER INTEGRATION

M. Falkenmark, Natural Science Research Council and Natural Resources Management Institute, Stockholm University, Sweden

ABSTRACT

Human livelihoods in drylands have in the past been addressed by different approaches : a reactive approach to drought and desertification with mitigation and repair as key concepts, and with a proactive approach, focused on complex water scarcity with coping as the key concept. The paper analyzes the livelihood problems from the latter perspective. The water scarcity to be coped with is complex and related to essentially four types of environmental vulnerability :

* lack of green water (root zone water) to sustain plant growth
* lack of blue water (feeding aquifers and rivers) to sustain human activities
* recurrent droughts as part of the hydroclimate
* vulnerable soils, that easily get impermeable through crust formation, causing desiccation of the landscape ("desertification")

The water scarcity escalates in response to rapidly increasing population pressure, creating risks for crop failures and growing morbidity/mortality as more people pollute the finite amount of water passing through the landscape. A diagnostic graph relates hydroclimatic preconditions to different coping techniques.

This paper builds upon two recent contributions to preparatory meetings within the "Drought and Desertification" convention negotiations (Falkenmark 1993b, 1994).

INTRODUCTION

At UNCED, the issue of human livelihoods in drylands attracted world-wide attention through the decision to ask United Nations' General Assembly to develop a convention on droughts and desertification. This decision raises a number of issues : what are the main problems and the main constraints of human life support in the tropical drylands? And how can these constraints be coped with ? What key obligations should the convention include and for whom ?

In Agenda 21 land and water are treated separately, land first in a set of chapters, and freshwater at the very end. This reflects a mental land/water dichotomy that neglects fundamental linkages between biomass production on land and water; the rain water partitioning in the contact with the ground layer, etc. In areas already under ecological stress and with a rapid population growth that will rapidly change the demand picture, such mental dichotomies act as barriers. In drylands, the issue is rather that water scarcity and land degradation are closely linked, and have therefore to be coped with in combined solutions.

The need to integrate land use and water management is even more evident when realizing that land use is not only water-dependent, but is also water-impacting. On the one hand many land-based activities are heavily water dependent: not only households and industry but also biomass production, since it is based on water passing through the plant from the roots to the foliage. Land use is in other words water-dependent for both biomass production, which stops without water, and societal production for which easy access to water is sort of a "lubricant", at least according to the experience in the industrialized countries. On the other hand, land use is water-impacting both through the effects of land use on rain water partitioning, groundwater recharge and stream flow, and the effects of the fact that water is a unique solvent and erosive substance, on continuous move in the landscape.

Thus, a proactive and integrated approach has to be taken to land use and water resources. Even today, in water scarce areas planning, does the supply-oriented approach still dominate. The classical question is "how much water do we need, and where do we get it" ? In a more and more water-stressed situation, competition however develops between different water use sectors, between upstream and downstream interests, and between urban and rural needs. The obvious solution is a discussion around the most worthwhile uses, trying to minimize other needs. In such a situation the task is to seek ways to successfully cope with actual environmental preconditions while satisfying societal demands. The key in this case is to take a resource-oriented approach by asking "how much water is there to share, and how can society best benefit from that limited amount".

This paper will analyze water scarcity in Subsaharan Africa and relate it to land use. It will take a future-oriented perspective with the next 30 years as time horizon, and define crucial coping strategy components. Instead of describing the problem as an issue of "drought and desertification", it will be approached from the perspective of how to cope with complex water scarcity. The rationale is the combination of two facts : man's genuine dependence on easy access to water, on the one hand, and the fact that water is scarce in several parallel respects in tropical drylands, on the other.

WATER - A VITAL, FINITE AND NON-SUBSTITUTABLE RESOURCE

A complex resource with multiple functions

In order to intellectually manage the problematique in the dry climate zone where droughts and desertification are a problem, it is necessary to realize that water is a complex resource : vital, non-substitutable and finite. Where water is lacking, people cannot survive but have to leave. This was illustrated by the risk of evacuation of the city of Bulawayo in Zimbabwe during the 1992 drought.

Water has basically four main functions which have to be taken into account and be well balanced in a coping policy :

* health function, manifested in the fundamental importance of safe drinking water as a basic precondition for socio-economic development (cf International Drinking Water Supply and Sanitation Decade 1981-90);
* habitat function in hosting aquatic ecosystems, which are easily disturbed when the water bodies get polluted;
* carrier function of dissolved and suspended material, picked up by the mobile

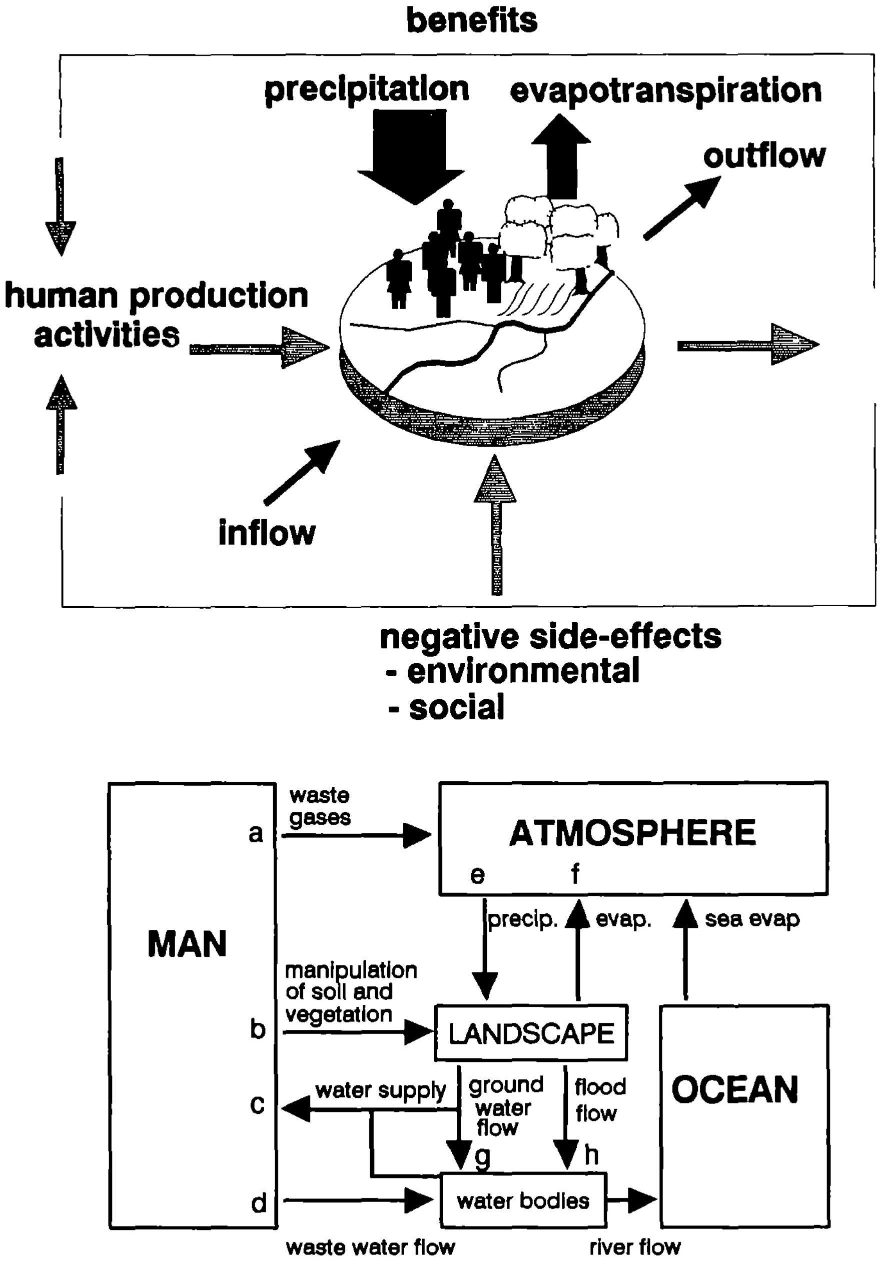

Fig. 1 **Fundamental land/water linkages.**

Upper figure : The landscape gets its life by being wettened from the atmosphere. It hosts the natural resources on which human production activities are based. Man-induced environmental problems are often side-effects of human activities in the landscape, aimed at achieving benefits for life quality and economic development.

Lower figure : The activities in the landscape take place at the mercy of the water cycle, the central clockwork of the biosphere. Black arrows (e,f,g,h) indicate water flows. Human interventions are of mainly four categories, here indicated by grey arrows (a,b,c,d) showing what part of the water cycle they primarily disturb. Any disturbances are caught, carried and propagated onwards by the water cycle.

water and carried along; this function is central in the land degradation processes (leaching of nutrients, erosion and sedimentation);

* production function, strongly stressed by the Dublin Conference as well as Agenda 21 (water as a so-called economic good, to be understood as water as an economic production factor). The production functions take on two main modes
  a) biomass production, operated by a flow of "green water", entering through the roots and leaving through the foliage; in the absence of "green water", photosynthesis stops altogether and the vegetation wilts;
  b) societal production in households and industry, based on "blue water", picked up through water supply systems.

Land/water linkages

Water cycle integrity links land use with water characteristics in aquifers and rivers. The landscape hosts the resources on which life security and economic development in poor countries depend (water, biomass, energy, minerals). Man has to manipulate the landscape (Fig. 1a) to get access to these resources, but through intricate linkage, controlled by natural laws, negative side effects tend to develop besides the intended benefits. Therefore human activities in the landscape are at the core of both developments, since they depend upon such activities, and environmental problems since they are produced as side effects of the same activities (Falkenmark and Subrapto, 1992).

The landscape gets its life by the passing water - therefore it is not surprising that a water cycle perspective on environmental problems is pedagogically clarifying. Most environmental problems are generated by four types of human interventions : (1) waste gases to atmosphere, (2) manipulation of soil and vegetation, (3) water withdrawals for water supply purposes, (4) waste water returned back to the landscape. Types 1 and 4 - more or less avoidable - dominate today's environmental problematique in the North (and indeed the paradigms behind Agenda 21). In the dry climate countries of the South, on the other hand the dominating types of intervention are 2 and 3 (and to some degree also 4) - the two former unavoidable and population driven (Fig. 1b).

The water movement through the landscape in a river basin links upstream activities with downstream opportunities/problems. The downstreamers are in a sense the prisoners of the upstreamers, since the latter control both the flow, the seasonality and the quality of the water available to the downstreamers

Environmental sustainability problems are basically related to three phenomena :

* waste handling habits (human waste, industrial waste);
* biomass dependence (agriculture, forestry); and
* water dependence (securing access to water).

The relative weight of these factors differ between the regions (temperate, dry climate regions, humid tropics) (Table 1).

Table 1 Typical key problems in different hydroclimates

region	*waste-related*		*biomass-related*		*water accessi-bility related*			*rapid popul. growth*
	human	industrial	agricult.	forestry	water supply overuse	water supply underuse	energy supply	
temperate		*			*		*	
dry tropics	*		*		*	*		*
humid tropics	*	*		*			*	*

HUNGER CRESCENT IN AFRICA

Many poor countries are poor also in water

Access to water represents a fundamental need in all societies:

* water is needed for sheer survival for the simple reason that life processes in the human body depend on continuous supply of water to compensate the daily losses of liquid through urine, sweating and respiration
* water is needed to make proper hygiene possible, cutting disease vectors which would otherwise bring bacteria infecting the human body
* water is needed in industry where many production processes are water-based
* water is needed in food production since the photosynthesis process depends on the presence of water in the root zone that can bring nutrients to the plant production process is water-operated

This deep dependence on water for so many human-related processes and activities does not make it the least surprising that the lowest-income countries are today accumulating in a zone characterized by the co-existence of several water scarcity indicators (Falkenmark, 1991): a climate with interchanging wet and dry seasons where a major part of the year is dry; recurrent droughts; and an extremely thirsty atmosphere (high potential evapotranspiration).

The close congruence in Figure 2 between the famine proneness in Africa and different water scarcity indicators suggests that there are links between the famine problem during drought years and complex water scarcity. The latter includes both scarcity of "green" water, i.e. water in the root zone, reflected in plant production difficulties, and scarcity of "blue" water, i.e. surplus rainfall, recharging aquifers and rivers.

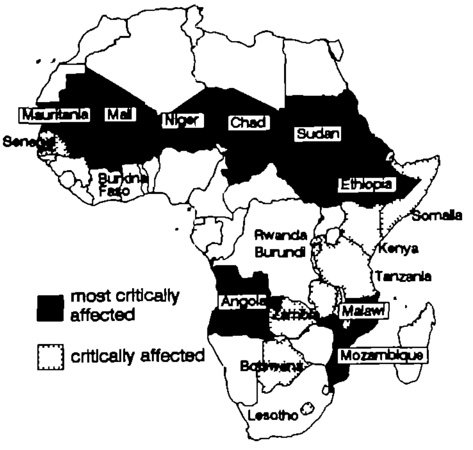

Fig. 2a Subsaharan countries suffering from severe famine during the 1984/85 drought.

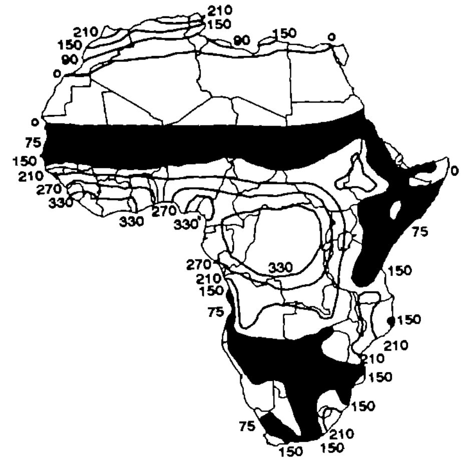

Fig. 2b Limited growing season (water scarcity A). Numbers indicate length of growing season according to FAO data. Dark area = 0-150 days.

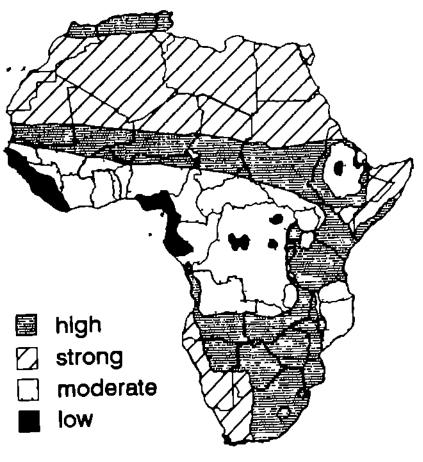

Fig. 2c Degrees of drought risk, based on number number of times in a 50-yr period with two drought years in a row (water scarcity B) according to FAO. High = 8 - 10 times; strong= 5 - 7 times; moderate = 3 - 4 times; low = 1 - 2 times.

Fig. 2d Strong land degradation according to UNEP (water scarcity C). Classification combines intensity with areal coverage.

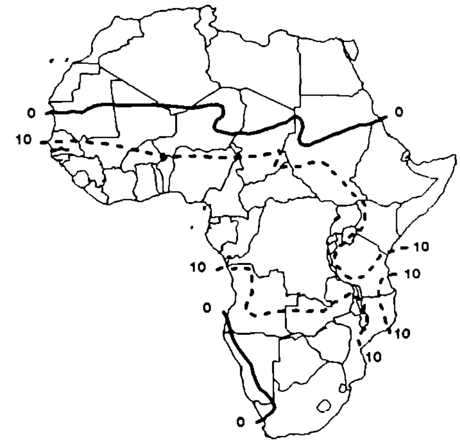

Fig. 2d Limited water surplus recharging aquifers and rivers (water scarcity D). Recharge is given in cm yr^{-1}. (Note : map lacks data for North Africa).

Fig. 2 Linkages between Subsaharan famine proneness and complex water scarcity.

Four modes of water scarcity

The emerging picture thus involves four parallel modes of water scarcity:

A. a short vegetation period, i.e. a period when there is enough "green" water in the root zone to sustain plant production. Since the rainfall is of a flashy and highly variable character, this corresponds to quite vulnerable plant production preconditions;

B. recurrent droughts as part of the climate, and related to the general atmospheric circulation, linking events over the Pacific like the El Nino-Southern Oscillation system with the monsoon circulation over Asia and Africa;

C. vulnerable soils which easily get impermeable through crust formation by physical or chemical processes; when the soil is impermeable the rain cannot infiltrate into the root zone and plant production stops;

D. very low surplus of rainwater available to recharge aquifers and rivers with "blue" water that can be made accessible to man and used while passing through the landscape towards the river mouth.

IMPLICATIONS OF POPULATION GROWTH

Before we go into a further discussion on crucial coping policies, it is necessary to clarify the effects of the ongoing population growth in terms of increased population pressure on the already limited amounts of "blue water", on which both drought proofing of biomass production and societal production in general depend. Population growth has often been treated as a taboo in past discussions on environment and development. That is extremely unfair to the South, since it delays the possibility to address the emerging problems.

Unavoidable population growth - a life support obligation

One useful way to address the issue is by introducing the distinction between unavoidable and avoidable population growth - well motivated by the fact that they have completely different policy implications (Fig. 3). The former refers to the children to be borne by the next generation of mothers, and before the size of the family can be brought down to reproduction level. This population increase is evidently a life support obligation to be properly planned for and should be discussed as such. The latter is on the other hand a question of family planning and child spacing and should be addressed as such. What will be discussed here is the former.

The escalating water scarcity scale

Arnestrand (pers. comm.) has estimated the number of people living in water stressed countries, i.e. countries with more than 600 persons per flow unit (one million cubic metres per year of "blue" water, Falkenmark, 1989). 600 p/flow unit is the level of

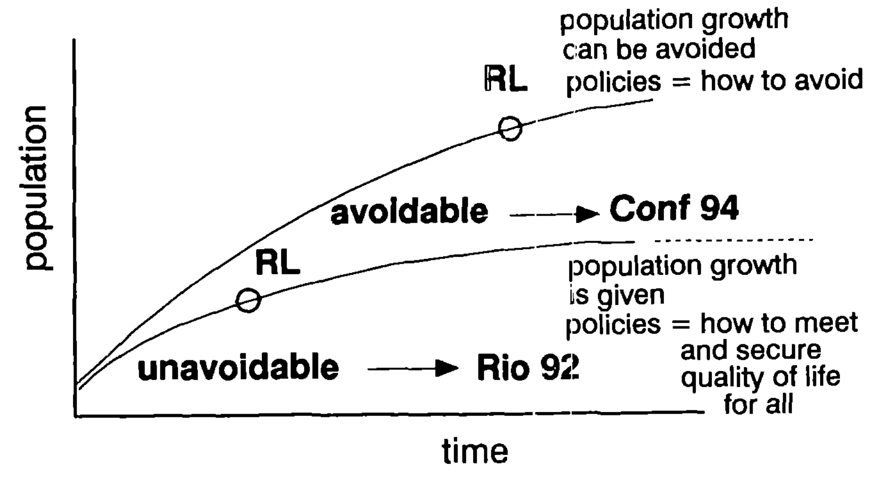

Fig. 3 A proposed distinction between unavoidable and avoidable population growth, depending on whether reproduction level (2 children per woman) can be achieved early or late in the next century.

population pressure on water where water stress can be expected. Beyond 1000 p/flow unit there is chronic water scarcity. He found that while there were by 1990 300 million living in such countries, the number will increase **tenfold** in the next few decades to over 3000 million by 2025 most of them in Africa and South Asia (Fig. 4).

When population increases, the level of water stress grows in terms of people per flow unit of water, in the end producing chronic water scarcity and severely complicating a multitude of deeply water depending activities.

These different modes of water scarcity are superimposed on each other with two main consequences (Fig. 5):

1) plant production difficulties, in other words continuous risk for crop failure;
2) more and more severe risks for water pollution as more and more individuals pollute each flow unit of water, leading to increasing morbidity and mortality.

The combination of water scarcity modes and population growth further characterizes a country's predicament: A, B, C and D combine into a risk spiral, driven by population increase and released during recurrent drought years. The combined effect by all four is demonstrated also by the congruence seen in Figure 2 of hydroclimatic maps and the pattern of famine-prone countries in Africa.

Water scarcity profiles

The dominating water scarcity problems in a particular region or country can be characterized by water scarcity profiles. Country profiles for the SADC region countries

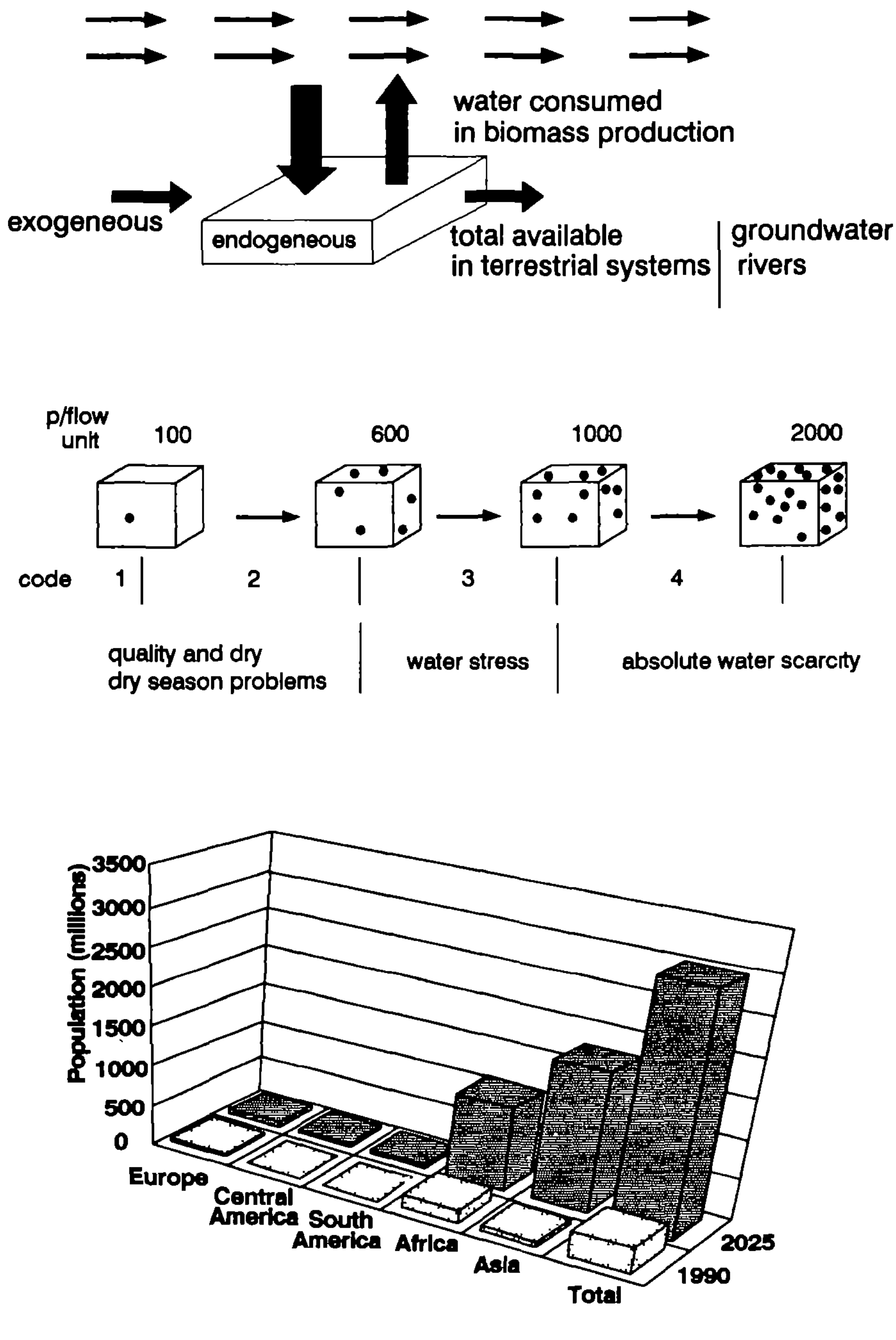

Fig. 4 Water availability as seen on a regional (country) scale. Upper figure (a) illustrates water availability as composed of an endogeneous component emerging from rainfall over the country and an exogeneous component emerging from rainfall over upstream countries. Mid figure (b) visualizes growing population pressure on a finite availability. Each cube represents one flow unit of water of one million cubic metres per year, each dot 100 individuals jointly depending on that water. Lower figure (c) indicates number of people by 1990 and 2025 AD, living in water-stressed countries, defined as more than 600 people per flow unit of available water (one million cubic metres per year). Columns show the different continents and the gross total. Source: Mikael Arnestrand, Natural Science research Council, Stockholm.

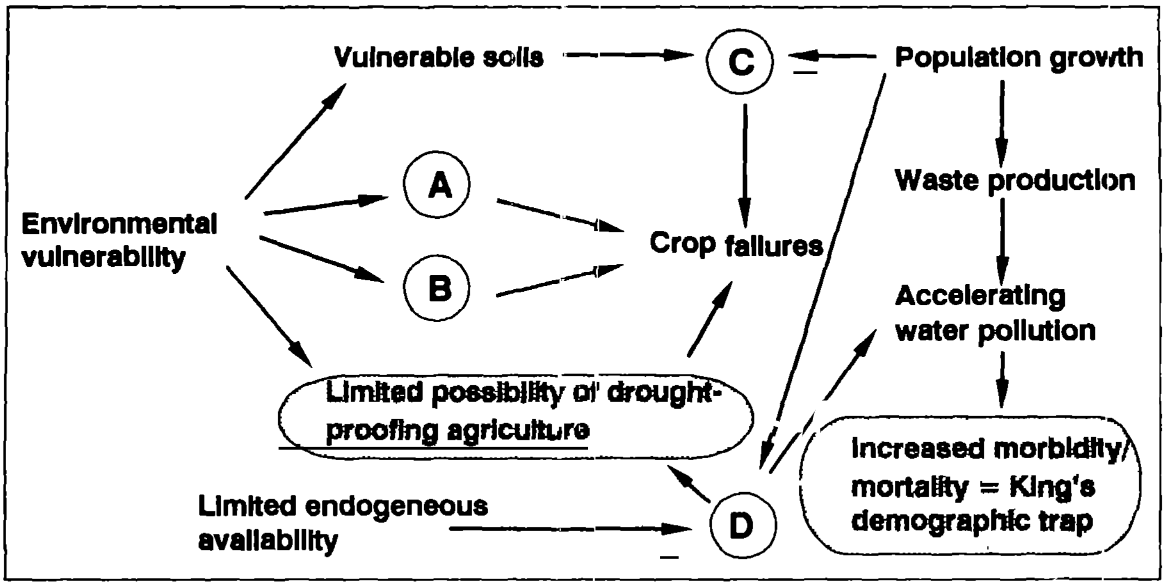

Fig. 5. Threats developing from the environmental vulnerability characterizing the dry climate tropics and subtropics as affected by rapid population growth. First and second order components are four main modes of water scarcity (A, B, C, D, see text) and particularly vulnerable soils. The grey fields indicate the main threats.

are shown in Table 2 (parentheses for "blue water" scarcity indicate the situation by 2025 as a result of population growth). For "blue water", the two dimensions are indicated: water stress in the sense of more than 600 inhabitants per one million cubic metres of water of annual recharge; and distribution problems due to large geographical differences within the country.

The Table shows that today - with a few exceptions - the problem constellation A-B-C is dominating in Subsaharan African drylands. The next few decades will see water scarcity D develop in response to the unavoidable population growth, producing more and more severe competition between countries sharing the international river basins. By 2025 most basin countries in the Nile, Zambezi and Limpopo will be water stressed or even suffer chronic water scarcity.

In India, for comparison purposes, the problem constellation A-B-C-D, is already widespread. Moreover water scarcity D has already begun to manifest itself in concrete terms. The reason is the large-scale irrigation development since independence which makes current per capita water demands considerably larger than in many non-irrigated African countries. Numerous conflicts have also developed between rural and urban areas, and between states sharing the same river basin.

Table 2 Water scarcity profiles of SADC countries

country	"green" scarcity	"blue scarcity" stress	distrib.	other problem
Botswana	A-B	-	*	C
Lesotho	A-B	(D-B)		C
Mozambique	A-B	(D-B)		C
Malawi	B	D-B		C
Namibia	A-B	D-B	*	C
South Africa	A-B	D-B	*	C
Tanzania	A-B	(D-B)		C
Zambia	A-B	-	*	C
Zimbabwe	A-B	D-B	*	C

Water scarcity implications for human livelihoods

How can a society cope with such harsh environmental preconditions ? Implications of "green" water scarcity is the need to take measures to drought-proof crop production (soil/water conservation, protective irrigation, etc.). Since droughts are recurrent parts of the climate the way to meet them is not emergency planning but to include them in the regular planning

As population grows the water scarcity predicament exacerbates in terms of increasing population per flow unit of water, or inversely, decreasing per capita availability. Just to retain even today's low water demand levels in Sub-saharan countries will call for considerable efforts in mobilizing a larger share of the potentially available water (pipelines, dams, etc). It is also necessary to keep down demand and to allocate water to the most worthwhile uses. This means seeing water as a production factor both for biomass production and for other societal production (irrespective of who pays).

Implications of the land degradation component C, which leads to flash floods, erosion, downstream inundations and silting, is soil conservation with adequate attention to potential vegetation-induced loss in terms of runoff.

Unless 100 % mobilization level can be achieved (corresponding to the water utilization level in Israel, i.e. large scale water storage, mainly subsurface), SADC-countries with water scarcity D will scarcely be able to retain the political goal of being self-sufficient in food production. If only 20 % utilization level is realistic in a time perspective of a few decades (i.e. moderate scale water storages) no SADC-country can be self-sufficient except Botswana - Botswana's decision to abandon that goal is therefore of considerable interest for the other countries.

COPING WITH WATER SCARCITY

What are the main issues to observe in coping with the complex water scarcity predicament, typical for many dryland countries ?

A new approach

Condensely formulated, the basic water management task is to successfully cope with the environmental preconditions while satisfying societal demands. The preconditions to cope with include scarcity of both "green" and "blue water", vulnerable soils, that easily get impermeable (so-called desertification), and recurrent droughts as part of the climate. The societal demands are driven by the population growth and closely related to aspirations of poverty eradication, employment, income raising, livelihood security, and economic production, etc. The demands include drinking water (health function), unpolluted aquatic ecosystems (habitat function), and production of biomass as well as other social production in cities and industry (resource function).

Addressing the vicious circle

It is crucial to avoid as far as possible the problems of the vicious circle in Figure 5. Key measures for that purpose are two :

1. to protect the soil from impermeabilization through soil conservation measures with the objective to allow all rainfall to infiltrate and form "green" water
2. to avoid to pollute the water by organized sanitation and waste-minimization in industry

Interesting success stories have been reported from India (Udgaonkar and Deshpande, 1987, Klemm, 1989, Datye and Paranjape, 1990).

Balancing biomass production against the "blue" water needed

When water is scarce the evident strategy must be to avoid as far as possible pure losses in terms of non-productive evaporation from moist surfaces in the landscape (Falkenmark and Rockström, 1993). This is equivalent to keep the soil surface vegetated. Such losses are huge in the drylands; field studies in the Sahelian region indicate that only some 15 % of the rainfall is used for plant production, i.e. forms productive "losses" to the atmosphere while 60 % evaporates as non-productive losses.

At the same time the biomass production cannot be driven too far so that no surplus is left to form "blue" water. Not only health protection depends on adequate water supply to settlements but also societal activities (and employment !) in the settlements depend on water. This problem will of course increase in weight as population grows and employment has to be organized for the growing number of individuals which cannot be absorbed in agricultural activities.

As regards the tree planting advocated as the best measure to protect soil permeability. It is important to look out for the environmental side effects of doing this on a too large scale. It is essential to learn the lesson of other regions, located in the same hydroclimatic zone and with equally high evaporative demand.

The high evaporative demand and the low runoff production ("blue water"), makes water availability in aquifers and rivers highly vulnerable to major upstream vegetation changes such as afforestation or agricultural intensification. Australian experiences of water-related consequences of the immigrants' clearing of virgin woodlands provides an informative lesson: the reduced transpiration produced widespread water logging, now counteracted by carefully controlled tree planting. In Subsaharan Africa, regional awareness is reflected in the South African experience : permits are required for forest plantations, based on whether the expected "costs" in terms of runoff are "affordable" or not. In certain areas, afforestation is forbidden altogether.

Basin scale approach to water sharing

Where water is scarce, the conventional approach of water allocation between use sectors has to be altered. At high levels of population pressures on water it is more a question of sharing the "blue" water that moves down the landscape above and below the ground. That water can be put to use as it moves downstream. As long as the water is not really consumed, it can be returned after use to be available for further use downstream. Since water in aquifers and rivers has earlier passed land and land use both depends on water and produces impacts on water (through water partitioning changes, and through pollution), land use has to be integrated with water resources management.

The integration has to be on the river basin level since upstream land use influences downstream opportunities. In general, upstream land uses influence the yield, seasonality and quality of the water available for downstream uses.

- forestry in upstream watersheds influences yield and seasonality of the water resource in the foothills, and therefore the opportunities for agriculture, industry and settlements in these locations

- the land use in both the upstream watersheds and the foothills determine quality yield and seasonality of the water resource in the river valley, and therefore the opportunities for agriculture, industry and settlements

- all upstream land use in the basin influences the opportunities in the delta area and the coastal waters through these upstream/downstream linkages

Also urban areas have to be seen in the river basin context, when water scarcity D develops. Their location may differ: close to the water divide, in the foothills, in the river valley, close to the mouth, or on the coastal fringe. The water problem profile varies with the location from groundwater pollution and over-exploitation in the first case, sedimentation and inundations in the second, to sedimentation and pollution in the third, to land subsidence, pollution and salinity intrusion in the last case. Providing water to supply rapidly growing urban areas has in the past been addressed as a technical problem, seeing the city more or less as an isolated island. An important management component to be aware of is upstream/downstream linkages in the basin: by upstream activities on the city, by city activities on other city activities and by city activities on water-dependent downstream activities (Falkenmark, 1993a).

CONCLUSIONS

When thinking of production from both "green" and "blue" water, the overall resource is basically the rainfall over the catchment. In the upstream areas, forests are needed to secure "blue" water recharge. This water is then available for sharing between upstream and downstream uses in the rest of the basin. The general coping strategy must involve best possible use of the limited water available. This means the following:

1. assessing the water availability and its fluctuations between wet and dry years

2. allocation to most worthwhile uses, seeing water as a production factor for both biomass production and other societal production

In the new approach to water resources management, proper attention has to be paid to land use since :

- access to water is a precondition for most types of land use

- polluting land use produces water pollution

- land use influences water partitioning both at the soil surface and in the root zone

Thus plans for land use and water management have to be properly integrated. Decisions about upstream land use are in reality equivalent to decisions about downstream water resources.

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AN OVERVIEW OF WATER RESOURCES DEVELOPMENT IN BOTSWANA

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ABSTRACT

This paper addresses the problem of water resource development faced in semi-desert regions, with specific reference to Botswana. The vagaries of climate, unpredictable and patchy rainfall and even more erratic runoff events all make hydrological modelling difficult; and the scarcity of long series of good quality hydrological data further add to the predicament. High evaporation and evapotranspiration losses present an additional challenge to water resources planners and practitioners particularly in view of the high cost of water. Lack of good dam sites is another problem in Botswana's ancient flat eroded landscape. This results in shallow ineffective reservoirs. Droughts perhaps a misnomer in a region characterised by long dry spells interspersed with shorter wet spells also add to the difficulties.

A long term perspective is thus vital, as is the need for establishing a good rapport amongst decision-makers, politicians, economists, environmentalists and the community at large. This is particularly important in a region where the provision of secure and sustainable water supplies will always be expensive and may conflict with other interests.

The Botswana National Master Water Plan has been developed to meet the challenge. A cornerstone of the plan is to integrate the expanding water supply system of Eastern Botswana, through the development of the North-South Carrier pipeline. A brief presentation and discussion of this is given along with other challenges faced by water resource planners, such as the development of the conjunctive use of ground and surface water resources.

INTRODUCTION

This Workshop is organised for discussions on water resources management relating to general long-term resource and environmental planning issues. For those of us who were part of the early discussions on the need for a national plan for water resources development in Botswana, these issues have a very familiar ring to them, perhaps, this Workshop could help in emphasising the need for good planning of the development of the nation's scarce water resources. It can contribute to the understanding of how interlinked the development of water is, not only with national development in an economic and social sense, but also with the environment. Water resources development based on a good understanding of what that development will mean to the environment, will become increasingly more important in a water short nation with little margin for mistakes.

The big questions are, how do we cater for safe and secure water for people and for industries and mines, now and in the future? How do we arrange for water when there is a choice between expedience and more costly, long term, sustainable solutions or put in simpler terms shall unrecharged groundwater be used if other possibilities exist? These are difficult questions and in Botswana's situation they are essential issues with important economic and political connotations.

The interaction of water development and the preservation of grazing land is one such area where the management of natural resources are delicately poised against economic and social considerations. As the understanding of how the environment reacts to overgrazing and how the healing mechanisms in nature function is increased, there will be possibilities to formulate policies, which may be more flexible and more in harmony with the various types of grazing land and therefore, in the longer term, will allow a sustainable economic use of the land.

Since the Workshop rationale is in many ways related to the original rationale for carrying out the National Water Master Plan the focus of my paper will be on the Master Plan.

Back in the early eighties, at the start of the long drought, it was realised that the national development was very vulnerable to droughts. The word 'development' is the operative word here. There has always been a deep understanding of the importance of water in semi-desert Botswana, where life itself throughout history has been linked to the availability of water and where functioning strategies have been worked out for coping with the unpredictability of rainfall. These strategies for life in rural Botswana were rational in the past and still are in many areas. It was realised, however, that towns and industries in the new emerging Botswana was much more dependent on secure water. Gaborone had been growing fast in the seventies and as this happened to be a period of good rains it was a new and frightening experience to have the prospects of a crippling water shortage in the Capital City. The looming crisis was averted but it was also realised that Botswana would have to come to grips with its water situation and decide on well coordinated cost-effective water development programmes and water development policies.

BACKGROUND

The rainfall varies from 650 mm in the extreme north to 250 mm in the south-west. Most rain falls in the hot summer period between December and March. In the eastern hardveld areas the rainfall is typically 450-550 mm. There are important wheat producing areas in the world with similar rainfall but in those areas the evaporation is less. In Botswana the evaporation is about 2000 mm, i.e. four times the average annual precipitation and this creates an endemic water deficit. The rainfall is also very erratic and patchy and it is common to have long dry spells during the wet season. Add to this that the soils are often sandy with low water holding capacities and you have all the ingredients required to make crop farming a very uncertain and risky business.

While rainfall shows large variations from year to year, river run-off is even more varying, as run-off is not only dependent on the rain but also on its intensity and if the good, high intensity run-off producing showers happen to fall on already wetted ground. The rainfall pattern that is best for crop farming, gentle and moderate rain well spread out over the growing season, is not what is required for good river flow. Drought means different things to the farmer and to the water engineer who is checking the inflow to his dams.

The average surface water run-off in Botswana has been estimated to 1.2 mm/yr. Comparable numbers for South Africa and Zimbabwe are nearly 50 mm and these countries are considered dry. Even Namibia and Saudi Arabia have higher average run-off. It is important to draw the attention to these numbers and this comparison in order to emphasise the problems facing Botswana and place them in some sort of international context. There is, indeed, ample justification for the often used expression that 'water is a scarce resource'. This is also true for groundwater, but first surface water will be discussed and factors that hamper the development and increase the cost of surface water considered.

SURFACE WATER

The high rate of evaporation is a major constraint and its negative effects are exacerbated by ineffective dam sites leading to shallow dams and consequently unfavourable relations between the volume of the water stored and the surface area. Good dam sites, which would provide deep effective storage reservoirs are a natural resource just not available in Botswana. Here we have to use dam sites, which require very long and therefore very expensive dams. To my knowledge there is only one reasonable dam site in Botswana and that is on the Kolobeng River not far from the Livingstone historical site. Unfortunately Kolobeng River is nothing but a trickle and in order to use the potential storage site water would have to be pumped there.

So what do we have so far. Low and erratic rainfall giving rise to even more erratic run-off, high evaporation and ineffective dam sites. The records of annual inflows to Gaborone Dam is a good example of variations of river flow from year to year (see Fig. 1). The most striking and also the most important feature of the inflow record are the long periods of consecutive dry years. The long term mean inflow based on the period 1924-1990 is 28.13

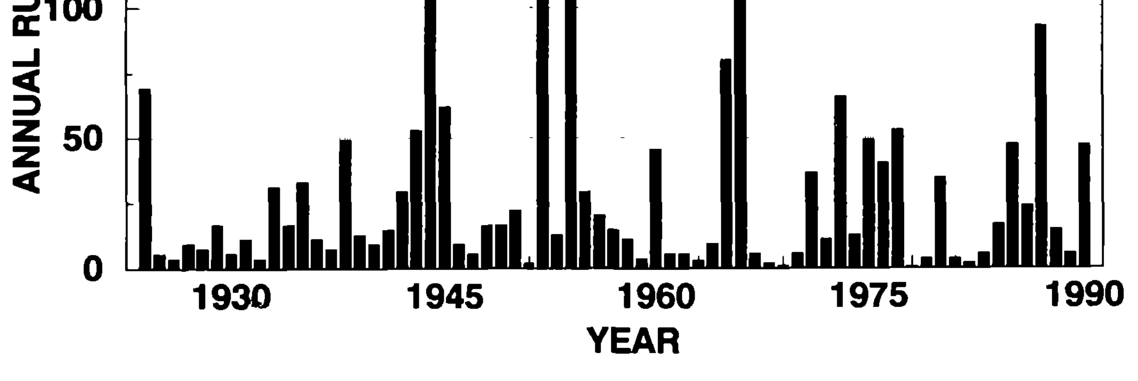

Fig. 1 Long-term inflow record for Gaborone Dam.

million cubic metres (MCM). The worst period was the long drought starting in 1925 and ending half-heartedly in 1933. There were 8 consecutive years with inflows varying from 3.3 to 16.4 mcm with a mean of no more than 7.5 mcm. The inflow variations in Notwane River is by no means extreme in Botswana. It is rather typical with a mean value that is about two times the median value emphasising the influence the few rare flood flows have on the mean. Quoting the Master Plan "the high temporal variability of run-off requires surface water storages to be large in relation to the mean annual run-off in order to provide carry-over for drought".

After the raising of Gaborone Dam the storage volume increased from about 37 to 144 mcm corresponding to more than 5 times the mean annual inflow and about 10 times the median. The old dam was built to the standard relation between storage capacity and MAR, (Mean Annual Run-off). In this region it was considered that the available storage volume should be between 1 to 1.5 times the MAR. The raising of the dam to correspond to 5 times the MAR can be seen as a measure of the almost desperate need to maximise the yield from the dam.

The yield from the raised dam calculated in accordance with the agreed safe yield criteria is 9.4 mcm/an. That means that even with this enormous storage volume seen in relation to the MAR, the reliable yield is no more than about 33% of the MAR. In the long run about 7% is 'lost' as spill down the river and 60% is lost to evaporation. The yield from Shashe Dam (see Fig. 2) is about 27% of the MAR - The size of the storage is about the same as the MAR but the rainfall is more reliable in the north. The yield from Lotsane River at a dam near Maunatala is on the other hand not more than about 10% of the MAR and the yield calculated for dams on the Limpopo main stem river vary from 15 to 20% of the MAR and these are yields from dams with a storage of about 4 times the MAR.

The low yield from dams due to unpredictable inflows and large evaporation losses from shallow reservoirs is a problem Botswana has to contend with and try to counteract as much as possible by ingenious water management. Under these very difficult conditions secure water supplies become expensive and it would be very unfair to compare the cost of safe water in Botswana with the cost of water in other countries where in some cases all you have to do is to stick a pump in a constantly flowing river.

RURAL WATER SUPPLY AND IRRIGATION

Returning to the Master Plan. There were a number of problems related to water, which came to the fore as a consequence of the persistent drought. Water supply for towns, Major Villages and other large concentrated water consumption centres required long term solutions - the most important being Gaborone with its satellites, as it was quite obvious that the locally available resources would not suffice much longer (see Figs 3 and 4).

The Rural Water Supply programmes based on groundwater also had to be seen in a wider context. Would the water last and could there be other and cheaper ways to provide the water. The 3 million head of cattle also drew most of their water from groundwater. Was there a conflict looming between water for cattle and water for people in the rural areas? And water for irrigation. Could it be made available such that Botswana would not have

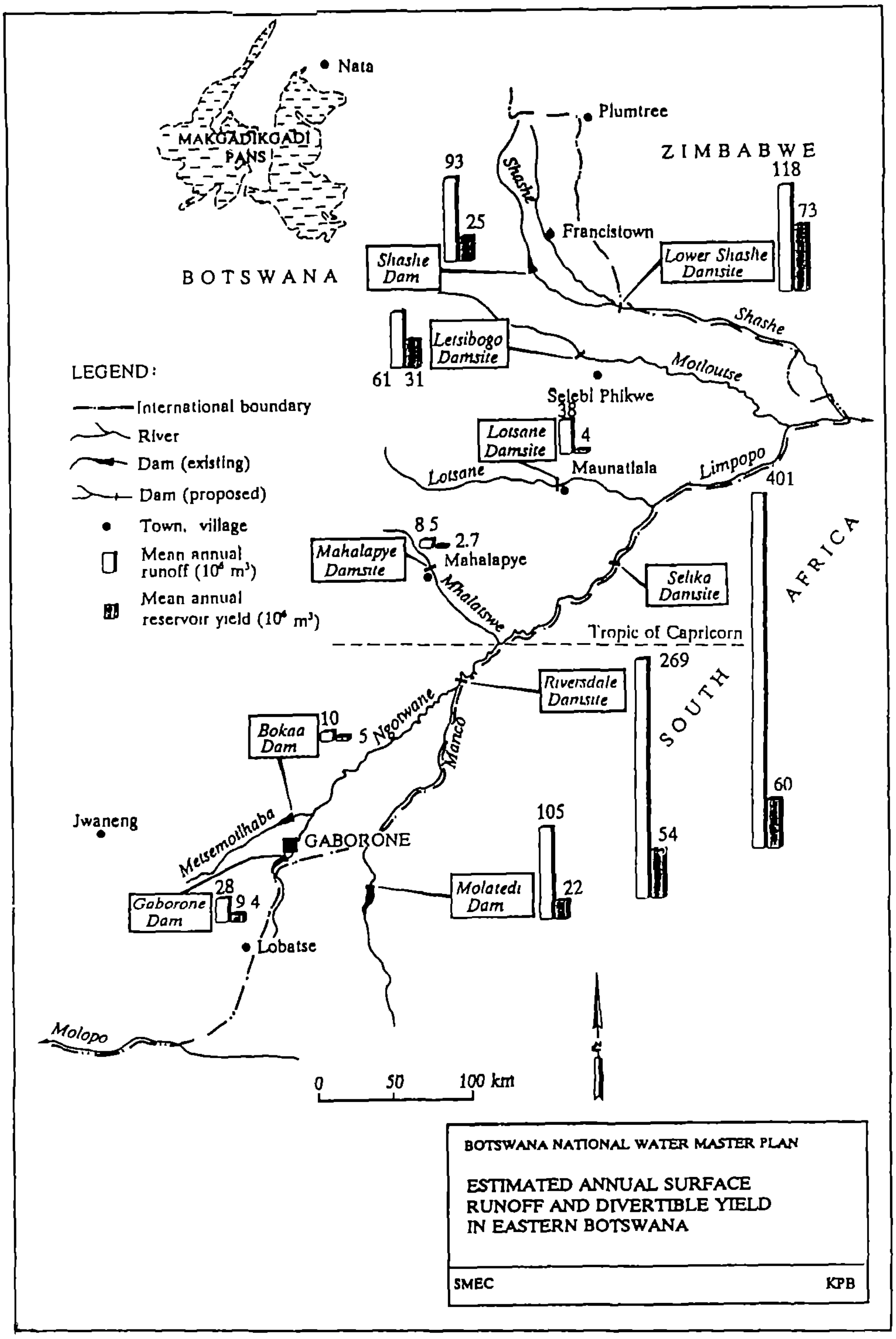

Fig. 2 Eastern Botswana dam sites and estimated annual surface runoff.

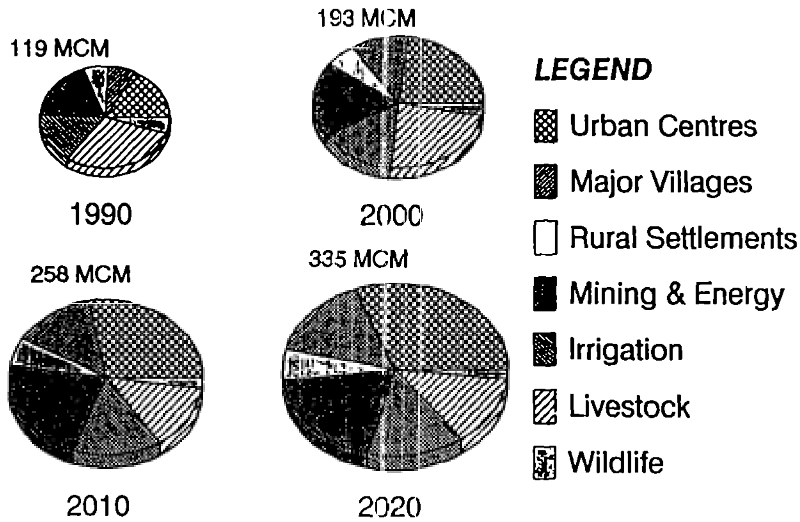

Fig. 3 Pie chart of growth in water demand for the different sectors (BNWMP, 1991).

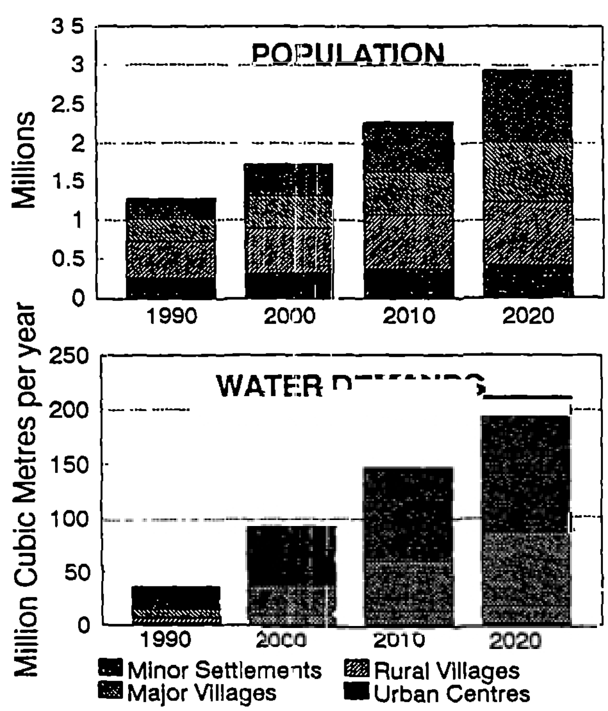

Fig. 4 Population growth and increase in water demand (1990-2020) (BNWMP, 1991).

to rely so heavily on imported food? There was no lack of good relevant questions as to how Botswana should use its waters.

The question related to irrigated crop farming was very prominent, especially among politicians, who during the drought were under pressure from their constituencies. For several years Botswana produced less than 10% of its staple food crops. This to be compared with the odd good years when even a small surplus could be produced. It is therefore easy to understand how demands for irrigation water came up. Irrigation was the solution to reliable food production and irrigation would provide much needed jobs and incomes in rural areas.

Irrigation became a thorny issue for the Master Plan. It was obvious that in a semi-desert country with no large perennial rivers, irrigation would not be something that would easily fit into a water development plan. At the same time the issue of irrigation was a very serious one and had to be seriously analyzed in a national plan for all water use. In the Terms of Reference for the Master Plan the consultants were required to look at irrigation in 4 different scenarios. Scenario 1 assumed no direct subsidies or price support, though no charge for water was envisaged. Scenario 2 assumed limited assistance for establishment, but no continuing subsidies in addition to free water at the farm gate as in Scenario 1. Scenario 3 assumed an objective of meeting 20% of the national food grain requirements from irrigation. Finally Scenario 4 assumed that the full costs of water are charged to the irrigators.

It was shown that, even assuming that water is supplied free to the farm, the only viable irrigation would be on small areas near Maun and in the Limpopo Valley. These would be utilising water for which there would be no significant competition from other users. Those were the expected answers but it was important to get them as a result of a solid analysis where potentially competing demands were included. What has been said now relates to food grains. The irrigation of horticultural crops for local markets could be a viable undertaking.

Large scale irrigation is no longer on the agenda and Botswana has adopted a strategy for food, which centres on security not necessarily self sufficiency and that strategy is more in harmony with the water situation.

It is perhaps instructive to look at a few numbers. With irrigation it is possible to get a crop of 6 tons of wheat per ha. With an irrigation efficiency of 60-65%, which also is reasonable, about 1300 - 400 = 900 mm irrigation water will be required. If a loaf of bread weighs 1/2 kg we will get 12 000 loaves from a hectare and we use a minimum of 9 000 cubic metres of water. This works out to 750 litres of water for a loaf of bread. To keep a cow in good health we need about 40 litres/day, which means that our loaf of bread corresponds to water for one cow for almost 3 weeks. The human per capita consumption in rural areas is less than 20 litres but assuming the 20 litres the loaf corresponds to water for one person for 5-6 weeks.

The above comparisons are perhaps not quite fair as there would seldom be a question of competition for the same drops of water but it is still thought provoking to see these numbers in a country where water is a scarce commodity. To use water other than that which is replenished, surface water or recharged groundwater, becomes doubtful to the point of being immoral. At this juncture it should be added that the analysis of irrigation in the Master Plan was purely based on hard numbers of water availability and economic viability. The Consultants had the benefit of access to very recent detailed studies of the feasibility of irrigation along the Limpopo and Nthane rivers and from a multipurpose dam on the Motloutse river, the Letsibogo Dam. The conclusion is that irrigation is, with few exceptions, just not a worthwhile viable undertaking in Botswana.

What I have been trying to impress is that water in Botswana is far too precious and far too expensive for irrigation purposes. There will always be those who do well using water from small earth dams on a particularly good patch of land and who know what the market wants, but irrigation will never be possible if there is competition for water.

There is an interesting possibility, which will become more interesting as time moves on. Return water from sewage treatment ponds may in the future be an important source for irrigation water. It is estimated that the return flow from Gaborone will reach 38 mcm/an in 2020 and this is a heavily regulated and steadily increasing flow with fairly small seasonal variations. Recycling of sewage water for domestic purposes may, however, be an attractive economic option and there may in the end be little water left for irrigation.

GROUNDWATER

One of the most important questions answered by the Master Plan relates to water availability in rural Botswana for people and for livestock. The question is, of course, if there is enough groundwater to cater for the water demand also in the future. Domestic human consumption is almost entirely based on groundwater whilst in practice about 30% of the livestock water demands are met from surface water, mainly during the wet season. It is interesting to note that it was estimated that the total livestock water demand in 1990 was about 5 times larger than the combined demand from rural villages and scattered rural population. The projections are that the water demand from the rural population will increase from 7 to 17 MCM/year over the 30 year planning horizon and that the livestock water demand will increase from 35 to 44 MCM/year over the next 10 years and then remain at that level. The 44 MCM/year corresponds to the number of livestock before the long drought in the eighties. Total numbers would have to be contained when this level is reached.

It was found that, at the national level, there is sufficient groundwater potential to meet the future demands of the rural population and of livestock except in a few isolated cases. Obviously the full solution is much more complicated than this simplified answer. The Master plan states; "The concepts involved in defining extractable groundwater resources and the techniques used to evaluate these resources are technically complex." The volume on Hydrogeology bears out that statement over several hundred pages. This is difficult material and I will draw the attention to only a couple of things.

The Master Plan planning horizon is 30 years and life will go on thereafter. Any really sustainable groundwater draw-off must be within what is recharged to the aquifer. The estimated mean annual recharge is about 3 mm if averaged over the whole of Botswana. You will remember that the surface water run-off averaged the same way is about 1.2

mm. However, just as only a small proportion of the surface run-off can de developed because of the lack of suitable dam sites, the high temporal variability of the run-off and the high evaporation rates, so only a small proportion of the groundwater recharge can be recovered because of the extremely large number of boreholes that would be required, the poor quality of the water and the high cost of development. There is a map of recharge in the plan indicating that the vast interior has a recharge less than 1 mm although the recharge in the populated eastern areas is rather better.

Botswana's future is in many ways linked to how well it will be able to manage its groundwater. The larger population concentrations and water demand centres in Eastern Botswana can be provided with water from surface sources but for rural Botswana groundwater will remain the only viable water resource. It is therefore extremely important that Botswana keeps on studying its groundwater and keeps on refining its understanding of how to manage it as a lasting resource.

WATER RESOURCE DEVELOPMENT IN EASTERN BOTSWANA

The Master Plan Terms of Reference drew the attention to the geographical imbalance between demand and available resources in South-Eastern Botswana, which would require inter-regional transfers of water. The consultants were required to explore the concept of an integrated network of sources linking all or most major consumption centres. An integrated water grid fed by the major potential water resources in Eastern Botswana should take full advantage of conjunctive use and system yield benefits.

The masterplan drew on recent, fully fledged feasibility studies of dam sites on all major rivers in Eastern Botswana; - Shashe River, Motloutse River, Lotsane River, Mahalapswe River and Metsemotlhaba River. In addition to these studies there were two studies on the Limpopo looking at several potential dam sites. It was indeed very fortunate that Government didn't shy away from the cost of the Master Plan after having spent all this money on studying the various potential components of the plan to feasibility level. The standard of the studies was very high and very consistent and the conditions for producing a solid plan were excellent. Before the Mater Plan team started reviewing the information there had been an enormous amount of work done on checking and verifying data on rainfall and run-off and there had been much valuable work done on hydrological modelling in addition to all the detailed work on the technical feasibility and estimates of costs.

In this climate it is absolutely vital to get the best possible information on the hydrological parameters and certainly the plan is based on the best estimates that could be made. In a short series of records every new year can make a lot of difference and the longer the record the better the estimate. In 1989 when the masterplanners started their work it was high time to produce a plan for how to provide Gaborone with more water and there was absolutely no time to wait for longer records. Hydrological models were used to extend the run-off series back to 1925, the same was done for all the potential dam sites, and in addition to that, stochastic records were produced for a much longer period.

A computer model was developed for Eastern Botswana called The South-East Botswana Water Resources Model. The model was developed to make it possible to examine the effects of different augmentation sequences and operating rules on the ability of the system to meet demands over the 30 year period, 1990 to 2020. The model could handle 11 surface reservoirs, 6 groundwater sources, 8 demand centres and 7 transfer pipelines. The simulation was carried out using a monthly time step. The model was designed to carry out either a traditional steady state analysis using a constant demand for the full period of the hydraulic record, or rising demand analysis to examine the performance of the system starting from present conditions.

Evaluation of the water systems in Botswana had previously been carried out using a simplified approach towards the estimation of system yields and performance. The analysis was based on the steady state simulation of individual sources in isolation. This is the standard method and most water resources augmentation plans are based on this approach. Its main drawbacks are that it can not evaluate the benefits of conjunctive use of resources and it can not be used to evaluate the performance of the system as a whole during periods of water stress. Such periods will occur when the demand on the system approaches the capacity of the existing sources and immediately after a new source is commissioned but yet has to fill for the first time.

The model was used to sift through a total of 36 alternative combinations for the supply of water to Greater Gaborone, Lobatse, Francistown, Selebi-Pikwe and to such major and rural villages that could benefit from connection to an integrated water transfer system. 22 of these were studied in more detail. The alternative sources encompassed: dams on the northern tributaries of the Limpopo, dams on the Limpopo, transfer from Vaalkop Dam in the RSA, "deep storages" to reduce evaporation, groundwater and recycled waste water.

The Eastern Botswana Model analysis was complemented by what was named the Economic Appraisal Model, which was used to compute the long run marginal cost of water, discounted present value and capital expenditure for the 22 options studied in detail.

The favoured development sequence was an option in which Letsibogo Dam on the Motloutse River and Stage One of the North South Carrier would be constructed first, followed by the Lower Shashe Dam and eventually a duplication of the North South Carrier.

The analysis of the potential water sources available to meet demands in Eastern Botswana and the recommendation of the most beneficial development sequence is the single most important component of the Master Plan. In Botswana the time when each community and demand centre can solve its own water supply is over. Botswana can not afford the sort of ad hoc, uncoordinated water development that has been possible in wetter parts of the world. The Master Plan has provided a framework for cost effective water development; and cost effectiveness is necessary in a situation where water for the Capital City and the most densely populated areas of the country will have to be fetched from a dam 360 km away.

The construction of the Letsibogo Dam and the NSC pipeline, complete with water treatment works and arrangements to provide water to designated points on route is costed to close to P 800 million. This is by any comparison a very large project and all interested parties, including future customers of that water, Government and potential financing institutions will quite naturally want to ask questions. Is this the best option and is it the most economic solution? On the strength of the Master Plan it is possible to say yes to those questions. Every conceivable option has been scrutinised and the recommended development sequence is the best. The water will come from a truly domestic national source fully under Botswana control. The transfer pipeline will follow the Gaborone-Francistown corridor complementing the existing infrastructure of road, railway and high tension electric power line by water, thereby adding considerably to the prerequisites for development along this corridor. It will connect the southern sources with sources in the north, which are exposed to a somewhat different hydrological regime, thereby giving additional system yield benefits and increasing the water supply security. It will pass some of the most promising groundwater aquifers in Botswana, which may provide strategic reserves to the water system.

P 800 million is very hefty price tag for a water project in a country with a total population of no more than 1.4 million. The Eastern Botswana integrated water system will, however, provide secure water supplies to about 450 000 people when it is commissioned in 1999 and in 10 years time and the total number of people served by the system will be at least 725 000 but more likely in the order of 900 000 people by 2020 corresponding to considerably more than about 1/3 of the whole population at that time.

Seen against the number of people, who will get their water supplies secured, the cost becomes more reasonable. Discussions of costs for a commodity that has no substitute are of course rather special. The long run marginal cost of water from the NSC project is estimated to about 5 P/m^3. This is quite a bit more than what the consumer pays for water in Gaborone to-day but it is less than the unit cost of water in Major Villages and only half the unit cost in Rural Villages. The difference is that in the villages the true cost is not charged to the consumer but is picked up by Government.

The NSC will have to be commissioned in 1999. The project will need to be on stream not later than in January 1999 if an acceptable level of water supply security is to be maintained. This deadline is based on runs of the Eastern Botswana Model using the latest information of water levels in the 3 reservoirs, which make up the basis for the existing water supply system to the Greater Gaborone area. This is an example of the value of the model. In standard water resources development planning concepts, a water supply system shall be augmented when the safe yield of the existing system has been reached. Anything later than that has always been considered as unacceptable as it would put the consumers at an unpermissible risk.

Greater Gaborone water demand will exceed the safe yield of the present system next year, 3 1/2 years before the NSC is scheduled to be in place. The reason we can allow deferring the project for all this time is that the model tells us that we can overdraw on the reservoirs, taking out more water than the safe yield for this time. There will be increased risks of manageable water supply deficits in 1997 and 1998, but it can be done, provided that the new source coming in is large, large enough to take up the whole demand on the system.

The Master Plan has provided Government with a very powerful planning tool. On the strength of the model simulations the NSC project can be deferred for 3 1/2 years and the economic saving of this deferment is in the order of P 225 million using a discount rate of 8%. The appropriate discount rate may be less but there can be no doubt that the cost of the Master Plan study will be handsomely repaid many times over just on these grounds alone.

Deferring the project assuming calculated risks is, however, not without its dangers. There is always the risk that a drought worse than anything experienced in the historic records hitting at the worst time. This risk may be small but there is a realistic risk in that the Letsibogo Dam does not fill in time to take over the job from the overdrawn dams in the south. The construction may be delayed shortening its 'warm up' time or the inflow may be very small when it is needed the most. In the Master Plan these risks are foreseen and the fall back position is to develop and connect the groundwater supplies from the Palla Road and Khurutse aquifers.

Groundwater sources connected to the system act like an insurance policy and as we learn to know more about their capacities and recharge characteristics we may be able to use our surface water harder, that is, we may be able to raise the safe yield from the system.

Finally it seems clear that the Master Plan will remain at the centre of water development, water management and water policy in Botswana for a long time. This does not mean that the present consultancy reports will be governing developments for a long time but that the Master Plan will remain alive and dynamic being updated, expanded and changed as new information becomes available and as new circumstances dictate. The really important thing is that Botswana takes good care of its precious drops of water and this can only be done effectively if water development is based on a good understanding of its water resources, good policies for how to allocate it and good plans for how to use it.

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ISSUES RAISED ON URBAN AND RURAL WATER SUPPLIES IN BOTSWANA

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ABSTRACT

The scarcity of water resources in Botswana and the long distance between the existing major resources and major Commercial/Industrial Centres necessitates more efficient treatment and distribution processes. This also implies that water losses in the distribution process should be controlled and reduced to minimum levels.

While clear water is a basic need for survival, the Botswana Government recognised during the early 1970's that the water supply service in Urban Centres, where the majority of the residents earned a regular income, can be self supporting, hence the decision to set up the Water Utilities Corporation, a parastatal body with commercial inclination. Major Villages and Peri-urban centres have shown in recent times, a tendency to move towards urbanisation and it may be in the interest of the economy in general for Government to gradually remove water supply subsidies in these Areas.

In order to be effective in the use of this scarce resource, Water Utilities Corporation and the Department of Water Affairs will need to improve efficiency in the following areas:

(i) Water treatment and distribution processes

(ii) Ensure that the unit cost of water is always affordable

ii) Effective control of water losses

(iv) Ensure that the water quality is compatible with international standards.

It will also be important to continuously educate the public and industry in general on the efficient use and water recycling techniques. The public for example will need to appreciate that a contribution by way of increased tariffs is required from them to finance major projects such as the North South Carrier and Letsibogo Dam.

INTRODUCTION

In Botswana the water sector is covered by three organisations, Water Utilities Corporation (WUC) supplying to 21.5 % of consumers in the six towns namely Gaborone, Francistown, Lobatse, Sowa Town and Selebi Phikwe with a total population of 286779, Department of Water Affairs (DWA) being responsible for 17 major village water supplies (MVWS) catering to 22.5 % of the country's population (299000 people), while 22 % of the nation's population in the rural villages is taken care of by the Councils. The balance 34 % of the population living in thinly populated settlements, mainly cattle posts, lands areas, etc. do not have a reliable source of water. They are dependent on their water supply from privately owned boreholes, hand dug open wells or hauling water from major villages or towns. The WUC is a parastatal organisation operating on commercial lines while the DWA and Rural Councils are Government Departments.Each of these three institutions have different organisation structures. The objective of all these organisations is to supply potable water in adequate quantities at an affordable cost.

This paper will concentrate on urban and major village water supplies although an occasional reference will also be made to the rural water supplies.

WATER TREATMENT AND DISTRIBUTION

Generally surface water is used for Urban Centres while ground water is common for major villages. The treatment process in urban areas comprises conventional screening, flocculation, rapid gravity filtration and disinfection systems. On the other hand ground water generally only requires disinfection before distribution.

In Gaborone for example the water demand peaks at 58 000 m^3 per day while the biggest major village consumes 3 000 m^3 per day. Peri-urban developments near Gaborone and Francistown such as Tlokweng, Mogoditshane and Tonota have grown significantly during recent years. These villages have had to be connected to the urban water systems due to the failure of their water sources.

It has been widely recognised that some of the 17 major villages have become urbanised and indeed their population is higher than that of some of the urban centres.

The commonest pipe materials used for water distribution are uPVC, asbestos cement, ductile iron, steel and HDPE. WUC has since decided to discontinue the use of AC pipes due to technical problems experienced during construction.

COST OF WATER IN MAJOR URBAN AREAS

Water Utilities Corporation is required to operate along commercial lines and presently supplies the requirements of Gaborone, Lobatse, Jwaneng, Francistown, Selebi-Phikwe and Sowa Town. Residents of these Urban Areas generally earn a regular income and Government had long recognised that as a result of this Criteria, the water supply service here can be self supporting hence the commercial inclination of the parastatal body.

Since its inception, in 1970, the Corporation embarked on major investments in water resources to meet the future water requirements. Major projects implemented to date are :

(i) Construction of Gaborone dam in 1964 and its subsequent raising in 1984.

(ii) Acquisition of assets comprising the Shashe Dam and trunk main to Selebi-Phikwe from Government in 1973.

iii) Construction of Bokaa Dam and pipeline to Gaborone in 1991.

(iv) Construction of a pipeline from Molatedi Dam to Gaborone.

(v) Construction of various treatment works and storage tanks at Gaborone, Francistown, Selebi-Phikwe, Lobatse and Jwaneng.

These projects were financed by loans from the Botswana Government and International financiers. These assets valued at P293 million as at March 1993 are essentially primary assets and therefore financed through the regular adjustment of the water tariff. The Corporation is also required by the World Bank to make a stipulated rate of return on the revalued assets e.g. 8% in Gaborone and 3% in Francistown. A combination of all these factors appear to make the unit cost of water in Botswana very expensive indeed.

Unlike many other Water Authorities in Southern African, the Corporation presently controls the water operation from source, through treatment and distribution up to the consumers water. This calls for a diverse range of Technical Skills in Civil, Mechanical, Electrical, Chemistry and Bacteriology.

The rapid economic growth of Botswana's major urban centres coupled with the fact that the associated water infrastructure has had to be developed quickly unlike in other Southern African Countries which paid for their assets long time ago has led to the comparatively high unit cost of water in Botswana. However the problem of the smaller consumer has been accommodated through the sliding scale tariff whereby his essential needs are available at a sub-economic rate while the larger consumer has a large bill to meet.

Resources are generally located far from demand centres and the flat topography necessitates pumping for long distances. The cost of power, imported chemicals, labour and maintenance is therefore such that the unit cost of water has to be expensive.

The DWA uses stepped tariff structure. The rates are low and subsidized for lower consumption of water. They shoot up and follow the WUC rates after a certain limit for higher consumption. In general the principle behind the tariff structure is that large consumers should subsidize the smaller ones. The Councils follow the DWA tariff structure.

WATER QUALITY AND POLLUTION CONTROL

Water is a dwindling asset and a finite resource. The limited water resources the country has, are divided into two categories : surface and groundwater resources. In rural Botswana the source for 90 % of the water for human consumption is groundwater. Ephemeral streams and rivers are traditional water sources. Almost all groundwater occurs in bedrock and is abstracted from deep boreholes in basement complex.

A Botswana Water Quality Surveillance Programme (BWASP) was carried out from 1980 to 1981 by the National Bacteriological Laboratory of Sweden (NBLS). The NBLS summarized the existing situation as "characterized by low per capita consumption, low population density, highly contaminated traditional water sources and deep groundwater sources of mainly intermediate to good bacteriological quality.

None of the Major Village Water Supplies (MVWS) depending on groundwater supply as a source had any form of purification equipment until 1987. Moshopa and Kasane were the only two villages where surface water was supplied to consumers after treating it through a treatment plant. A modern treatment plant with extensive treatment facilities to treat water from the Chobe River for Kasane residents was commissioned in 1992. The old outdated treatment plant still continues to serve the Moshopa residents.

The sterilization treatment which until 1988 consisted of drip feeding has been upgraded to gaseous chlorination in most of the MVWS. At present 10 of the 17 MVWS has these facilities available.

There has been a manifold increase in the industrial development due to an economic boom the country has enjoyed in the last decade. This has resulted into a large scale migration of the population from the rural areas to the major villages. With this growth in population and increased water demand, more water has to be pumped resulting into lowering of the groundwater table, thereby inducing saline and brackish waters of high iron contents, sulphates, etc. which are very aggressive.

This development has led to increased pollution and water quality hazards to the source, surface and groundwater resources. Stringent water quality controls in the form of treatment through water treatment plants and by regular water quality monitoring are therefore needed to make use of the scarce resources in order to meet the insatiable demand of the fast growing population.

The Water Quality Monitoring and Pollution Control Section of the Operation and Maintenance Division is responsible for monitoring the quality of drinking water and control of pollution of the water resources under jurisdiction of the Department of Water Affairs.

There is a central laboratory in Gaborone where the chemical and bacteriological analyses of surface water, groundwater and waste water samples takes place. The laboratory also provides the necessary chemical analytical services to other Government Departments and Parastatal Organisations. Farmers, private drilling companies and Consultants engaged in the Department's projects are also assisted with water analysis services. The various District Councils, Water and Health Units also submit water samples to the laboratory on a routine basis.

In addition the mobile laboratory goes out to the various Districts for water quality monitoring as well as on site sanitary inspection. Endeavours are made to visit each District at least once a year. In the North West there is a small laboratory in Maun where some chemical and bacteriological parameters can be determined. This laboratory serves the region around Maun. There is also a smaller laboratory in Kasane serving the water treatment plant there.

This year so far, seven hundred and twenty eight samples have been received by the laboratory in Gaborone; an example is given in Table 1. below. The Southern District and the Kgalagadi District have been covered by the mobile laboratory this year.

Table 1. Water sample analysis by DWA.

sample :	Water Utilities Corporation treated water results
date sampled :	20/01/1994
date analyzed:	20/01 - 24/01/1994

pH	7.95
conductivity	140 microSiemens/cm
Total Dissolved Solids	96.2 mg/l
turbidity	0.8 ntu
free residual chlorine	1.0 mg/l
total residual chlorine	1.0 mg/l
alkalinity	76.0 mg/l
bicarbonate	92.7 mg/l
carbonate	0.0 mg/l
total hardness	76.0 mg/l
Calcium hardness	56.0 mg/l
Calcium	22.4 mg/l
Magnesium	4.9 mg/l
Chloride	9.9 mg/l
Sulphate	1.0 mg/l
Nitrate	2.0 mg/l
Fluoride	0.32 mg/l
Silicate	3.83 mg/l
Sodium	6.0 mg/l
Potassium	4.0 mg/l
Coliforms 37^{0}C	NIL
Coliforms 44^{0}C	NIL

Water Quality data is stored in the water quality data base housed in the laboratory. This is updated continuously.

The Pollution Control Inspectorate carries out regular inspection of industries, municipalities and mines. This year inspections have been carried out at the B.C.L. mine in Selebi Phikwe, Mining and Development Gold Mine in Francistown.

The Water Apportionment Board also gets advise from the Pollution Control Section. The Board is responsible for issuing effluent discharge permits and also takes action on industries or institutions which do not comply with the recommended pollution control measures.

A consultancy to delineate Protection Zones for major aquifers and dams has been completed. Final reports have just been received.

WATER LOSSES

Water losses in the system are generally between 15 and 25% but can go up to 35% in some places particularly where the pipework is old. This is of primary concern to both WUC and DWA.

The Corporation monitors losses due to spillage and other causes regularly. Zone metering has been introduced in the distribution system from which possible night flows will be monitored.

CONCLUSION

While potable water in Botswana generally complies with international standards, problems associated with scarcity, system water losses, pollution and cost of water need to be addressed now and in the future.

WATER DEMAND FORECASTING
THE CASE OF THE BOTSWANA NATIONAL WATER MASTER PLAN

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ABSTRACT

Water scarcity in arid and semi-arid countries such as Botswana, the ever growing demands and competition for financial resources between the different sectors, call for judicious planning to ensure rational water management and development strategies. Water demand forecasting is an indispensable tool in water resources planning which enables appropriate water development strategies to be drawn up, with due regard to climatic and financial constraints. Notwithstanding the risks involved in projecting into the future, several methodologies for water demand projections have been developed and these have been used in the water sector. This paper describes some of these methodologies, their use and the difficulties involved in demand forecasting, with particular reference to the Botswana National Water Master Plan. Water demand forecasting during the NWMP studies enabled the geographic distribution of current and future demands to be determined and appropriate water development strategies for meeting the demands in the long term to be drawn up. This allows adequate time to plan for development projects with long lead-in periods, such as projects requiring international co-operation.

INTRODUCTION

Forecasting of future requirements of any commodity is an integral part of any planning activity and can either be included explicitly or implicitly in the planning process. In the water sector planning for future developments or operations involves short, medium or long term forecasting, depending on the stage of water resources planning. The different planning stages can be considered to be (i) strategic planning, which requires forecasting on a long term basis, typically in excess of 30 years, to enable the development of long term plans and policies to cater for development projects requiring a long lead in time (ii) Investment appraisal, requiring medium to long term forecasting to enable appraisal and decisions to be made on options for immediate development or investment (iii) engineering design, requiring medium term forecasting (10-15 years) to enable an appropriate design horizon to be set and (iv) operational planning which requires short term planning (daily, weekly, monthly or seasonal) to enable an appropriate operation of existing schemes to meet short term variation in demands.

Several methods for estimating future demands have been used in the water sector. Three main approaches are described here.

(a) **Extrapolation**: This involves the derivation of forecasts based on past trends. This approach requires long time series and does not take other factors which influence demands into consideration. In Botswana the absence of long time series and factors such as rapid economic growth, severe restrictions during times of droughts and other supply constraints make past trends an unreliable guide to future demands.

(b) **Judgmental Forecasting:** This approach relies on the strategic planner to make the required judgments according to experience and observed trend indicators. The judgmental approach is normally combined with other methods because an element of judgement is always required to reconcile the results obtained with reality or with adopted trend indicators.

(c) **Components Approach:** In this approach the water demands are estimated from consideration of other variables which are considered to have an influence on the demands. This approach has the major advantage of allowing factors which influence the demands, such as socio-economic parameters and development policies, to be incorporated in the forecasting process.

FACTORS INFLUENCING WATER DEMANDS

(i) Demographic considerations

These include such factors as the rate of population growth and population distribution. In forecasting future demands the rate of growth of the population to be served has to be determined. This involves adopting an appropriate growth rate. In Botswana the Central Statistics Office (CSO) and the Department of Town and Regional Planning (DTRP) regularly undertake exercises to estimate future population growth rates based on intercensal information available. In addition to this a population census is undertaken every ten years, falling on the second year of each decade. The National Master Plan Phase I population

Table 1. Estimated population growth rates.

ANNUAL GROWTH RATES (%)				
PERIOD	CSO Low	CSO Medium	CSO High	DTRP
1981 - 86	3.64	3.69	3.79	3.23
1986 - 91	3.47	3.62	3.92	3.07
1991 - 96	3.26	3.50	3.94	3.01
1996 - 01	3.07	3.39	3.39	2.95
2001 - 06	2.89	3.31	4.07	2.77
2006 - 11	2.66	3.20	4.14	2.54
Source: MFDP 1987 and DTRP				

forecasts were based on the CSO and DTRDP forecasts future growth rates. These were later revised during phase II when the preliminary results of the 1991 population census became available. The DTRP and CSO estimated natural national population growth rates used in the NWMP studies are shown in Table 1 above.

The NWMP phase 1 adopted the CSO low and medium forecasts as the medium and high forecasts respectively and the DTRP forecasts as the NWMP low forecast. When the 1991 preliminary census results became available these were used as the base for estimating future population figures, using the growth rates given above.

The increasing urbanisation in the country has meant that the population growth rate in the urban centres is much higher than in the rural areas. Population estimates were made on a settlement by settlement basis for centres with a population of more than 2000 inhabitants, to enable appropriate rates of growth to be used for each settlement. The estimated population figures per settlement type are summarised in the Table 2.

Table 2. Population figures for different settlement types.

CATEGORY	POPULATION (10^3)			
	1990	2000	2010	2020
Urban centres	263	428	631	924
Major villages	288	415	569	775
Rural villages	480	587	700	818
Other settlements	251	309	365	412
TOTAL	1 282	1 739	2 265	2 929

(ii) Socio-Economic Factors

Factors such as improvement in standards of living and changes in household income have an effect on the water demands and consumption patterns. In assessing future water demands the proposed housing and institutional developments in each centre had to be taken into consideration. It has been shown that the standard of housing has an influence on the water demand, with people living in high cost housing consuming more water than those in low cost and high density housing estates.

It is expected that the standard of living will continue to improve in all centres and consequently the level of service and per capita demands from the water sector will increase in tandem. The inclusion of this aspect in the water demand estimation enables different rates of increase of per capita demands to be used in different settlements. The villages in the vicinity of the urban centres, that is the peri-urban centres, have a consumption pattern and growth in demand similar to that of the urban centres as most people living in these centres are employed in the nearby urban areas. It is expected that the other settlements further from the urban centres will also expect a level of service approaching that of the peri-urban settlements.

(iii) Economic factors

When the economy of a country is doing well many economic activities are undertaken which lead to both a permanent and temporary increase in water consumption. This refers to activities such as increased construction, industrialisation and institutional expansion.

Although the rate of economic growth in Botswana has declined since the boom period during which the National Water Master Plan studies were undertaken, the economy is still expected to show a positive growth rate for some time to come. Several settlements are expected to have possibilities for future industrial and commercial development. In those settlements where the latest physical plans made allowance for industrial and commercial development the estimate of future water demands included the possible demands from such developments. The magnitude of the estimated commercial and industrial demands depends on the perceived likelihood of the anticipated development materialising.

BOTSWANA NATIONAL WATER MASTER PLAN DEMAND FORECASTS

Methodology

The method used to determining the demands during the National Water Master Plan studies was to separate the demands into different components according to the types of demands. This allowed the demands for different settlements to be estimated in accordance with the prevailing factors affecting each component of the demands. The demand components are as shown in Figure 1.

(a) Domestic Demands

This component of demand is controlled by demographic factors, per capita demands and the socio-economic set-up. Using the projected population figures and appropriate per capita demands, domestic demands were forecast for each settlement type. Demands were determined for individual urban, peri-urban and major villages whereas for smaller settlements the demands were calculated on a regional basis.

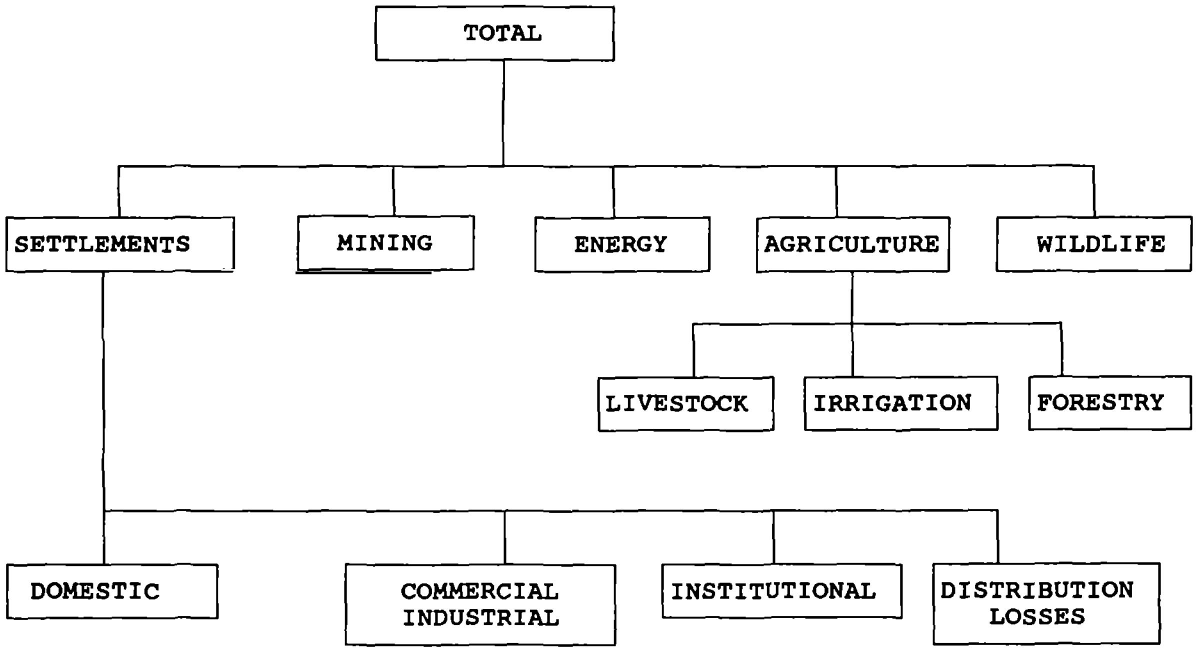

Fig. 1. Water demand components.

The per capita demand depends on the type of supply connection or level of service (that is whether stand pipe, yard connection or house connection), household income, standard of housing, type of sanitation and, to some extent, the water pricing policy.

In forecasting demands for urban and peri-urban areas consideration was given to future planned housing developments, in the short term and on socio-economic projections for the long term. In the major villages the future growth in demands were based on the expected level of service by comparing consumption figures in villages at different stages of development to provide guidance for future demand growth patterns. Past experience in the water sector has shown that under favourable socio-economic conditions people will tend to have yard connections followed by house connections at a later stage, with increasing per capita consumption with each stage.

(b) Commercial and Industrial Demands:

The industrial and commercial demand estimates were based on information obtained from the relevant authorities on likely future developments. Alternative industrial/commercial growth scenarios were set up which could be linked to a particular demand centre in the model as appropriate. The different scenarios are shown in Table 4. Except for some villages where there are large commercial entities such as the Botswana Meat Commission (BMC), the industrial and commercial demands are mainly in the urban centres.

(c) Institutional Demands:

The institutional demands were estimated in a similar fashion to the industrial/commercial demands, that is basing the demands for each settlement on the expected level of future institutional development according to the alternative scenarios shown in Table 3.

Table 3. Industrial/commercial and institutional demand growth.

CATEGORY		SCENARIO	DEMAND GROWTH RATE (% p/a)			
Industry Commerce	Inst		1990-95	1996-00	2001-10	2011-20
C1	I1	High plus	20	10	5	3
C2	I2	High	15	10	5	3
C3	I3	Medium	10	8	5	3
C4	I4	Low	5	5	3	3
C5	I5	Nominal	3	3	3	3

(d) System Losses:

Losses sustained during distribution were also included in the demands. These are estimated at 20% of total production for urban centres and 25% for other centres.

(e) Other Demands:

In addition to the demand components given above consideration was given to other demands which were obtained separately. These are mining, energy, irrigation and livestock demands.

CONSOLIDATED WATER DEMANDS

The total demands estimated for the NWMP planning period are given in Table 4 and are shown graphically in Figure 2. The geographical distribution of the demands is such that by far the largest proportion of demand is in the eastern part of the country, particularly in the south east. By the end of the planning period the urban centres will

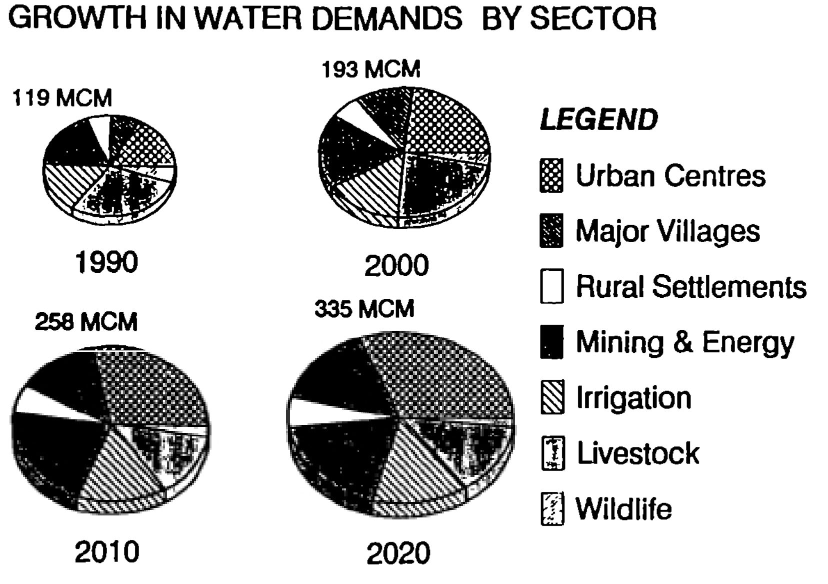

Fig. 2 Consolidated water demands (1990-2020) after BNWMP, 1991.

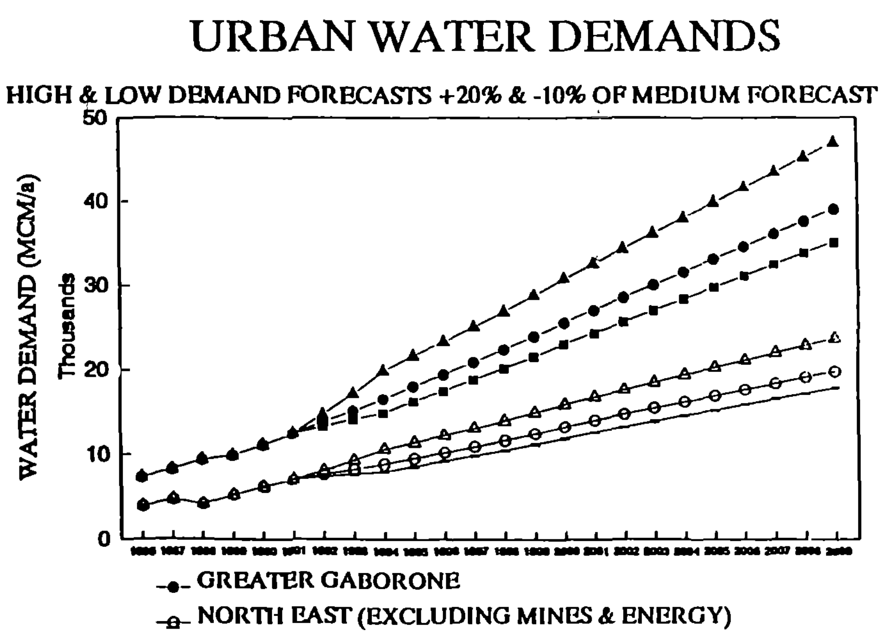

Fig. 3 Alternative demand forecasts (BNWMP, 1991).

account for more than 60% of the settlement demands even though only about 30% of the population will be residing in these centres. Gaborone, which currently accounts for 30% of the consumption will use about 40% of total settlement demand by 2020. This is due to the higher levels of service in the urban areas coupled with rates of population growth above the natural rate as result of urban migration.

TABLE 4: CONSOLIDATED WATER DEMANDS ESTIMATES

CATEGORY	WATER DEMAND (10^6m^3)			
	1990	2000	2010	2020
Urban centres	20.9	45.0	72.0	103.1
Major villages	8.2	21.5	35.4	51.9
Rural villages	5.3	9.2	12.7	16.5
Other settlements	1.9	2.3	2.7	3.0
Mining and Energy	22.5	35.7	56.5	63.7
Livestock	35.3	44.8	34.3	44.1
Irrigation & Forestry	18.9	28.9	38.5	46.9
Wildlife	6.0	6.0	6.0	6.0
TOTAL	119.0	193.4	258.1	335.2

DISCUSSION

The main problems with water demand forecasting is the uncertainty inherent in attempting to predict the future. This is an unavoidable problem since future occurrences which may alter the status of factors affecting water demands can not be known in advance. Uncertainty increases with increased forecasting period. The geographic distribution of the demands may also alter as a result of changes in factors affecting the demands such as the change in the status of a settlement as an institutional or commercial centre.

To cater for the uncertainty in forecasting alternative demand forecasts can be undertaken using different demand scenarios obtained by varying the growth rates. In the NWMP the alternative demand scenarios were achieved by varying the medium demand forecasts by -10% and +20% for the low and high demand scenarios respectively. The alternative forecasts are illustrated in Figure 3, which shows the growth in demands in the north-east and south-east centres.

Water resources planning should cater for the uncertainty in demand forecasting during the development of strategies for meeting the projected demands. Water development strategies should be flexible enough to cater for any variations, either downwards or upwards, from the anticipated demand growth.

As stated above most of the demands are in the urban centres and major villages in the eastern corridor, particularly Gaborone and its surrounding villages.

To meet demands in the eastern corridor the NWMP recommends a staged water resources development which involves inter-basin water transfer schemes to form an integrated water supply system. The recommended development strategy allows for waste water re-use and demand management exercises which may be used to reduce growth in demands and hence delay the development of new sources. This development strategy has the required flexibility to cater for the uncertainty inherent in demand forecasting.

CONCLUSION

The National Water Master Plan water demand forecasts provide a sound basis for short and long term water resources planning. The methodology adopted for the estimation of demands took due cognisance of the factors affecting the demands, which makes the projections more realistic. The use of alternative growth scenarios have enabled an assessment of the effects of the uncertainty in the projected demands.

It is however essential that the forecasts be reviewed regularly and adjusted according to the status of the factors controlling the demands changes.

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SUSTAINABILITY AND COST EFFICIENCY ASPECTS OF THE PRESENT DISTRICT COUNCILS WATER SUPPLY SERVICES

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ABSTRACT

The primary aims of District Council water supply services are:

- to improve the health conditions of the rural population by providing adequate quantity and quality of water.

- to enhance the rural economy in order to facilitate better job creation activities in the rural areas.

Currently, District Councils are responsible for the operation and maintenance of about 450 rural village water supply schemes. This figure is growing by 5 to 10 every year. The capital investment and running costs (in present value) of one scheme is approximately P135,000 per year using the present techniques and management structures. This entails that District Councils need a minimum of P60.7 million a year only for their water supply service sector.

Given the insignificant direct revenue collected by the Districts and the fact that 95% of the total water supply service costs originate from Central Governments as grants, the sustainability of the present financial arrangement is highly uncertain.

An unacceptable level of water losses is another serious drawback. About 20% to 40% of village water supply produced is lost to evaporation due to inefficient monitoring and limited user concerns. Technically and financially speaking, this means that an average of 2.9 million cubic metres of water which is equivalent to about P9 million a year is lost. This is an enormous waste of a scarce resource.

To make the District Council water supply services more cost effective and sustainable, the current service provision approach needs to be improved. In this paper, brief background of the rural village water supply systems currently in operation, major problems and uncertainties faced and some potential solutions to tackle these problems are presented for discussion.

BACKGROUND

Village water supply service provision is one of the Ministry of Local Government's statutory functions. The Ministry of Local Government, Lands and Housing (MLGLH), ensures that the District councils provide reliable and sustainable water supply services to all the people who are living in officially recognized villages.

According to the National Settlement Policy Draft Document and the Department of Town and Regional Planning Guide Document, a settlement is defined as a village when it fulfils the following major criteria:

- It should have a minimum population of 500 people.
- it should be situated at least 15 km away from the nearby village.
- it should have headman, VDC, etc.

Since water supply is a basic need infrastructural service, village level water supply service is established in all newly confirmed villages before any other infrastructural services such as primary education, health, etc. is established.

At present, there are about 450 villages throughout the country provided with village level water supply services. This number grows by 5 to 10 every year. The growth come as a result of roughly 5 to 10 settlements getting village status every year.

According to the currently adopted standards, a typical village level water supply scheme consists of the following major water supply components.

VILLAGE WATER SUPPLY SYSTEM COMPONENTS

The main water sources for most villages is groundwater based. Usually more than two boreholes are drilled for a village. The relatively high yielding boreholes are used as main operational sources whilst the relatively low yielding are used as backup sources in case the main sources fail. The ground water tables for all these boreholes vary very much from place to place. It varies in depth from about 50m to 150m. In most cases, the drawdown level of these boreholes fluctuates substantially. During droughts, many boreholes dry up rapidly.

Energy and Pumping Components

Currently, diesel engine, mainly of the Lister type are used in order to produce power. In some cases, power from the National grid is also used. Because of it's lower running costs and its environmental acceptability, District Councils are now encouraged to use more power from the National grid when that is possible.

To pump water from the boreholes to the required elevation, Mono Pumps of various capacities are used. In situations where the energy source is grid power, submersible pumps are used.

Transmission Main

To convey water from the boreholes to the supply areas, a transmission main mostly of PVC pipe is used. According to the adopted design standards, this main must be equipped with necessary air, washout, gate and section valves.

Distribution Network

To cover all supply areas in a village, a branched system is used. But in some cases especially in relatively larger villages, even looped and combined (looped+branch) systems are also used.

Storage Tank

In order to meet short time balancing and emergency requirements, every scheme is provided with adequate storage tank facilities. The most commonly used tank types are; galvanized steel tanks and glass reinforced plastic tanks. Most of these tanks are elevated on 6 to 8 m steel stands.

As per the currently adopted design standards, most of the schemes are designed to provide 10 years projected service demands. After 10 years, the schemes are evaluated for major rehabilitation and upgrading so that the service level provided by these schemes will cope with the population growth and socio-economic development in the villages. During the present plan period (NDP7), roughly 30 to 40 schemes are rehabilitated/upgraded every year.

The service levels provided by these schemes are measured using the currently adopted Botswana Rural Village Water Supply Design Manual. According to this manual, minimum requirements are to be achieved. This include the following:

- 30 litre per person per day through public stand pipes.
- people should not walk more than 400m one way to fetch water
- one public stand pipe with two taps to serve roughly about 200 people
- storage facilities with a capacity that can meet a short time balancing and 48 hours emergency requirements.
- a backup water source in order to secure availability of water in case main operational sources fail, etc.

As noted above, the village water supply system is not a simple technology. The number of the schemes are too many and the standards adopted are relatively high. In order to operate these schemes efficiently capable organizational and management set-up are required.

INSTITUTIONAL ARRANGEMENTS

Three organizations are involved in the village water supply development, operation/maintenance, rehabilitation and upgrading activities.

a) DEPARTMENT OF WATER AFFAIRS (DWA)

At present, DWA has the responsibilities for the initial development of all village water supply schemes as per the adopted standards. Design and construction of large rehabilitation schemes are also done by or through DWA on behalf of the Ministry of Local Government, Lands and Housing.

b) DISTRICT COUNCILS (DCs)

Except the 17 major villages, all village water supply schemes in Botswana are fully operated and maintained by the District Council Water Departments. Recently, after gradual improvement of the water Departments' capacities, minor village water supply rehabilitation and upgrading works are also done by these Departments.

c) MINISTRY OF LOCAL GOVERNMENT, LANDS AND HOUSING (MLGLH)

The Ministry has the over all responsibility in ensuring that District Councils provide water supply services to all the people who are living in villages as per the adopted standards. The Ministry is also responsible for planning, budgeting, programming and monitoring implementation of all rehabilitation and upgrading activities. MLGLH coordinates all the activities done by these three organizations.

According to the current set-up, provision of village level water supply service is a very expensive exercise. The schemes are not generating any revenue to cover even their running costs. There are three major costs involved:

VILLAGE WATER SUPPLY COSTS

Running Costs

These include, operations, maintenance, minor replacement and overhead costs. To run a typical village water supply, it costs roughly about P50,000 per year in current prices.

Upgrading and Rehabilitation Costs

In order to make the service provision cope with the demands, each scheme is rehabilitated/upgraded once every 10 years. It costs about P800,000 to fully rehabilitate and upgrade a scheme. This means a depreciation of about P80,000 every year.

Subsidy Costs

It costs about P2200 to connect a supply system to a private consumer (yard/house connection). The fee charged today is only P500. This implies that the District Councils should subsidise about P1700 per private connection applicants approved every year. Assuming 3 private connection is approved every year per a village, subsidy cost is 3x1700 = P5100.

Total Costs

Total Cost (Running+Depreciation+Subsidy Costs)

The total cost per village per year is therefore = P135000. To run all the 450 schemes required about P60.7 million per a year.

PROBLEMS AND UNCERTAINTIES ENCOUNTERED.

During the initial development of most of the village water supply schemes, higher emphasis was given to minimize initial capital cost by drilling the boreholes close to the villages (within 5 to 7 km radius) against transporting water of relatively more reliable from longer distance. This development approach has now resulted in many problems. Many boreholes dry up every year especially during droughts because they were drilled on relatively poor aquifers.In such situations therefore, it has been very difficult to secure reliable and sustainable services. It is also very costly to drill a number of boreholes every year to replace dried up boreholes.

As a result of the lack of users participation in money or labour, the relatively huge organizational structure of the Districts Water Departments which implies very high overhead costs and a sparse spread of services in order to cover all villages up to 500 people make the District Water supply service very costly to the Government. District Councils are not generating enough net revenue to cover all their service costs. They are heavily dependent on deficit grants from the Central Government whilst the service costs increase linearly with the increasing number of new villages every year. This situation has created uncertainty in correctly forecasting the sustainability of the current types of service provision.

Another serious problem is the "Unacceptable level of water losses". According to our own estimates, about 20 to 40 % of the present water supply is loss to evaporation through leakages, spillage, overflow, etc.

Assuming 70 cubic meter per day per village is an average water production, the average total water losses per a year in all the 450 villages is estimated to be about 3.5 million cubic meter of water. In money terms, this costs about P10.5 million. Considering the small size of the systems, it is not cost effective to accept such huge level of losses.

All the major problems discussed above and other additional problems raise questions about the sustainability and cost efficiency of the current District Councils water supply services. Hence, these problems need to be tackled as soon as possible.

SUGGESTIONS FOR DISCUSSION

The water development approach currently adopted should carefully be re-examined. High emphasis should not only be given to minimize initial capital costs. Reliability and sustainability of the water sources should be developed and given equal status.

The building up of huge water Departments at District and Sub-District level needs to be revisited considering the future economic reality. Situations must be created to make the water users actively participate both in labour and funding to operate and maintain their own water supply schemes.

Operation, maintenance and monitoring performances should be improved in order to reduce the unacceptable level of water losses currently experienced. For such small systems, these losses should not exceed 10% of the produced water. To achieve this, there must be close cooperation between the District Water Departments and the users. Each scheme should have at least one water users committee in order to monitor and report service performances, misuse of water, causes for losses, etc. MLGLH should also be actively involved in monitoring operational performances of all the schemes in the country.

In order to introduce necessary water use restriction and other necessary measures which might help to minimize misuse of water, i.e. control illegal connections and vandalism of the systems, etc, all the schemes should be gazetted. Water Authority for District Water Supply schemes should be given to MLGLH in order that MLGLH to coordinate in issue water Authority Rights to each Council Secretary/District Commissioner according to established procedures.

Unless full cost recovery is achieved, provision of water supply services to individual households through private connections should be avoided. Water consumption tariffs and private connection fee subsidies for individual house holds should completely be stopped.

If these were implemented, it is believed that the cost efficiency and sustainability of the present District Water Supply services could be improved substantially.

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LONG-TERM WATER RESOURCE MANAGEMENT IN BOTSWANA: THE CASE FOR CONTROLLING DEMAND

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ABSTRACT

Demand for water in Botswana is increasing at an extremely rapid rate due to population growth, increasing reticulation of supplies, expanding number of household connections and growing industrial requirements. The conventional way to approach the planning of future water provision has been to project current demand on the basis of existing trends and to then consider all the technically and economically viable means of meeting the projected future demand.

The feasibility of sustaining current and future projected levels of per capita demand in the long term does not previously seem to have been seriously questioned. This is surprising given the scarcity of water in Botswana, the increasing pollution problems around urban centres and the fact that groundwater recharge rates in much of the country are minimal and the resource is effectively being mined in many areas.

There is thus a strong case for a new approach to water resource management in Botswana. This new approach should be based on the premise that the long term supply is limited. The allocation of this scarce resource should be both equitable and related to realistic estimates of the long term sustainable supply.

In order to control supply a degree of rationing through price control, raising public awareness and restrictions on certain types of water use would be necessary. Other approaches to regulating supply such as a co-ordinated National Water Conservation Strategy based on more water reuse and recycling, the widespread introduction of rainwater catchment systems and water saving devices also need to be actively researched and promoted.

INTRODUCTION

Water is a very scarce resource in Botswana, groundwater sources are limited and opportunities for developing surface water resources within the country are fraught with constraints. The possibilities for future reliance on water resources originating mainly outside the country and shared with other states are likely to be subject to fierce competition due to rapidly growing water demand throughout the region.

The rapidly growing demand for water driven by population growth and economic development is creating considerable pressure to develop Botswana's limited water resources. The population has already increased around tenfold this century and is set to double again in the next 25 years according to estimated projections in the Botswana National Water Master Plan (BNWMP Vol.1 1991): - (see Krook Figure 1 in these proceedings).

Since 1972 nearly 350 new village water supply schemes generally involving the reticulation of a pumped borehole source equipped with a Lister diesel engine have been introduced through the Village Water Supply Programme. This has provided new public standpost supplies and some private connections to more than 400,000 villagers throughout the country and has brought the total number of rural village water supplies to about 450. The improved levels of provision have resulted in a parallel increase in per capita consumption as water supplies are brought closer to the consumers.

In major villages and urban centres where household connections are becoming increasingly common growth in per capita demand has also increased steadily and due to rapid urbanization the increase in total demand has been dramatic. Data from the Botswana National Water Master Plan (BNWMP 1991) suggest that it will be in the larger settlements that future increases in demand will be the greatest. While demand is forecast to increase nearly 3-fold in rural settlements between 1990-2020 it is predicted to increase almost 5-fold in urban centres and more than 6-fold in major villages, (see Gieske, Table 1 in these proceedings). While total demand for water is predicted to increase less than 3 fold between 1990 and 2020 only slightly faster than population growth, water consumption in settlements is forecast to rise almost 5-fold from 36 million m^3 to 175 million m^3 annually, BNWMP (1991). These trends are illustrated in Figure 1, and are significant as they suggest that any attempts to manage the growth in demand needs to target supplies to settlements, where consumption is projected to increase from less than 1/3 of total water demand in 1990 to well over 1/2 by 2020.

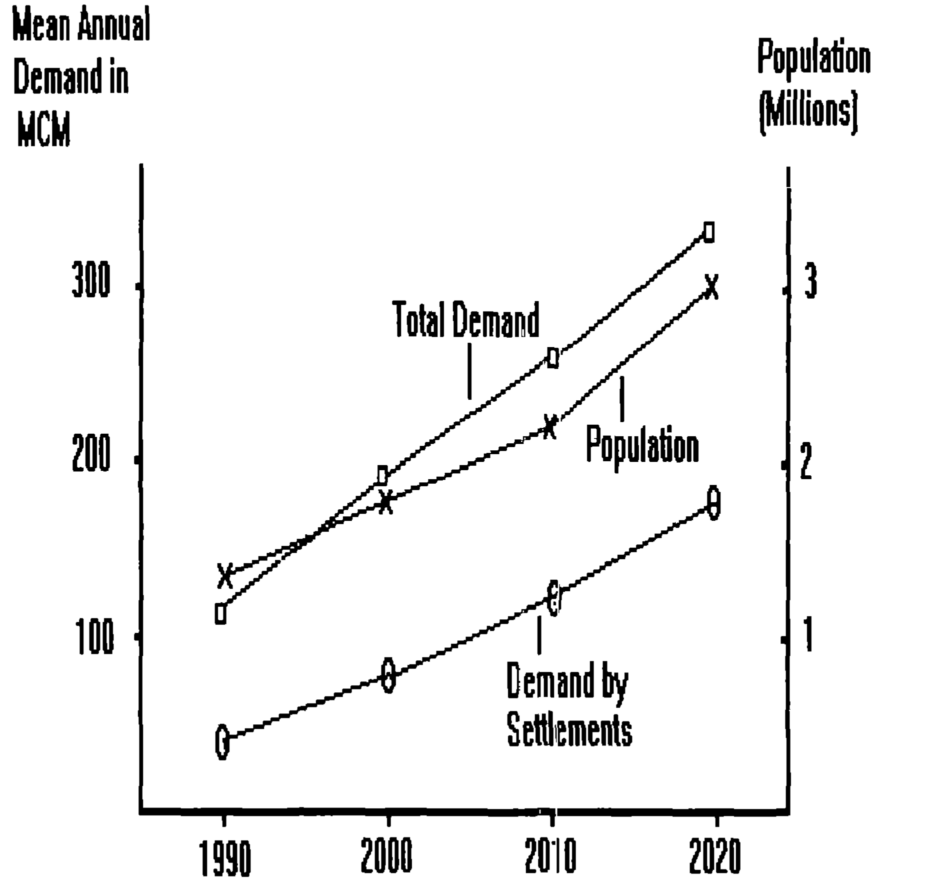

Fig. 1 Population and Water Demand Projections for Settlements 1990-2020
Based on data from BNMWP (1991).

While population growth and urbanization are likely to be important factors in the predicted increase in demand, it is also assumed that per capita consumption will also increase substantially in most types of settlement. Based on projections for the period 1990-2020 shown in Table 1, per capita consumption is expected to rise by more than 50% in urban centres, more than 60% in rural villages and by 110% in major villages.

Table 1 **Projected Per Capita Water Demands in Botswana 1990-2020 Shown in litres/day. (Source: BNWMP 1991)**

	1990	2000	2010	2020
URBAN CENTRES	205	259	289	309
MAJOR VILLAGES	69	111	128	145
RURAL VILLAGES	34	45	52	55
OTHER SETTLEMENTS	20	20	20	20
OVERALL	83	127	152	168

N.B. Figures exclude water demand for livestock, irrigation, wildlife, energy and mining.

Although the rate of increase in demand is likely to slow down, there are likely to be many competing pressures creating obstacles to any attempts at continually increasing the level of supply.

THE PROBLEM OF SUSTAINING HIGH LEVELS OF SUPPLY

The BNWMP completed in 1991 arguably offers a well thought out strategy for meeting predicted water demand over the next few decades. Nevertheless, even if increases in demand do start to slow down towards the end of the plan period, several factors mitigate against the possibility of meeting the predicted high levels of water demand over the longer term beyond 2020 (at least if unacceptable trade-offs are to be avoided). These factors include the fact that:

i. Most groundwater resources are effectively being 'mined' due to very low rates of recharge (<3 mm/year if averaged over the whole country). If continually over-exploited these will eventually be exhausted.

ii. Large surface reservoirs already inefficient due to the high rates of evaporation and the erratic and unpredictable nature of runoff events, will become increasingly ineffective during the next century as they silt up. Once filled with sediment alternative dam-sites are limited due to the flat terrain.

iii. Natural surface water resources in the North of Botswana are remote from the main demand centre in the Southeast and are likely to be subjected to increased pressure from neighbouring countries who are showing increasing interest in exploiting more of the waters of the Zambezi system and the waters draining into the Okavango Delta.

iv. Pollution of ground and surface waters may limit the quantity of high quality water available in the future.

v. There maybe negative effects of a major economic down turn in the future should the diamond market collapse or even just decline slowly.

vi. The impact of future climatic change whether induced by global warming or simply due to a natural fluctuation may reduce available water resources.

A NEW APPROACH TO WATER RESOURCE MANAGEMENT

While the BNWMP offers a way forward for meeting future water demands over the next 25 years, based around the construction of the N-S Carrier and associated reservoirs, in a country such as Botswana where water is such a critical resource it would seem prudent to also give consideration to a longer time frame. Ideally, water resource planners should be addressing themselves to the challenge of starting to develop systems and approaches which are sustainable not just for a few decades but for several generations, if not indefinitely.

The most rational approach to this problem is that outlined by Falkenmark (1991, 1994), i.e. to adopt a resource oriented approach to determine how much water is readily available and how this water can best be allocated. This is very different from the conventional approach adopted by the BNWMP, which simply predicts how much water the country will need over a fixed time period and then considers the simplest and cheapest ways to get it.

In the NCS water is identified as a key development constraint. While it is obviously desirable to increase the availability of water in parallel with the ongoing development of Botswana's infrastructure and economy we need to be wary of the risk of forgetting what a scarce resource water is and thereby creating the potential for another 'water crisis', such as that experienced during the drought of the 1980's. The danger is that during wetter periods people will get used to consuming increasing quantities of water (including considerable waste and avoidable losses). This practice is actually already being encouraged of in a variety of ways; these include the following:

- many BHC flats in urban centres have washing facilities and outside taps which can be used by occupants for washing clothes, watering gardens, washing cars etc.. free of charge, since BHC picks up the bill.

- most rain and stormwater runoff generally goes to waste being neither collected or directed onto vegetation where it can be of some use.

- avoidable losses through leakage of pipes, taps etc..

- government provides a very substantial subsidy especially for supplies outside the major urban centres, according to the BNWMP (1992) this amounts to almost P1/m^3.

- water from standposts in both towns and villages are free, household connections in rural areas are subsidized by more than P3000 per household amounting to an annual subsidy from Government of more than P2 million nationwide to the highest rural domestic consumers, (see Hagos in these proceedings).

While much of the increasing water demand is the unavoidable result of population growth, urbanization and economic development there is clearly considerable potential for increasing water conservation and demand control measures. The effectiveness of the restrictions on water consumption introduced in Gaborone in 1983 which resulted in a 50% drop in demand illustrate that substantial increases in the more efficient use of the resource can be achieved relatively easily, Arntzen (1986).

The reuse of effluent also offers considerable potential for helping to reduce demand on primary water sources. This is already being used in a limited way in the Gaborone area, for watering the golf course and providing water to the game park. With return flows in Gaborone predicted to rise from about 5 million to 38 million between 1990-2020 according to estimates in the BNMWP (1991) it seems highly likely that this source will be increasingly developed in future for irrigation of parks, recreational facilities and even crops as well as to provide raw water to recharge aquifers and reservoirs used for domestic supplies.

DEMAND CONTROL MECHANISMS

A variety of demand control mechanisms could be introduced and existing ones employed more effectively to significantly curb Botswana's water demand over coming decades. These mechanisms are generally based on attempts to reduce, reuse and recycle water resources. In addition to these classic '3 R's' of resource conservation, in the case of water conservation a fourth 'R' for 'redirecting' runoff and storm water also has a significant role to play in reducing overall demands on conventional sources of supply. Attempts to redirect and store runoff for future use involve practices such as rainwater collection, rainwater harvesting, runoff farming and runoff gardening and the use of more drought resistant plants, Figure 2. These are important components of any water conservation strategy which potentially can have an important impact on reducing demand. Demand control mechanisms can be sub-divided into those measures which are specifically aimed at directly reducing consumption and those which indirectly help to reduce demand through water conservation measures.

Reducing Demand

Among the mechanisms available for directly reducing consumption are:-

i. Price Control - This is an extremely effective way of penalizing over-consumption and waste of water particularly in the urban centres where demand is greatest. Although a relatively successful price control strategy is already being applied through a stepped tariff system considerable potential still exists for achieving further reductions in demand through applying higher tariffs in certain cases. Despite increases and a re-structuring of the tariff bands in November 1993, in response to recommendations in the BNWMP (1992) supposedly with among others the purpose of encouraging lower levels of consumption, when inflation is taken into account the adjusted figures in real terms show only a small increase in the lower bands compared to prices in the 1980's. In the critical highest bands where the greatest potential savings are possible from major institutional users the water is actually cheaper now (at least for those using $>50m^3$/month) than at anytime in the last 10 years, (see Arntzen in these proceedings).

   Another approach to price control could be the automatic application of higher tariffs during drought periods. These higher drought tariffs would come into effect across the board when reservoir capacities falls below some pre-determined critical level. The additional levy would be most effective if the biggest consumers were hit hardest. For example while a 25% increase might be applied for band 1 (0-10 m^3/month), a 50% increase for band 2 (11-15 m^3/month), 75% to band 3 (16-25 m^3/month) a full 100% increase applied to band 4 consumers (>25 m^3 /month).

ii. Reducing Water Pressure - During severe drought periods the pressure of the water in the mains could be reduced. Careful planning and design considerations are, however, necessary to ensure consumers in tall buildings or on higher ground are not unfairly effected.

iii. Water Restrictions - a number of permanent restrictions relating to the size of private lawns, swimming pools etc.. could also be introduced. While at one level this may seem an unreasonable infringement on personal liberty, when one considers that the annual evaporation from a 10m x 15m pool is around $300m^3$ equivalent to the mean annual total domestic consumption of more than 10 people or more than 50 times the water used by an average Lands Area dweller, such restrictions might be viewed in a different light. A lawn with an area of 15m x 20m can be equally as thirsty.

Water Conservation

Apart from reducing direct consumption, active water conservation measures are required including both reusing/recycling waste water and redirecting rainwater runoff for useful purposes. While at a macro level, the government has encouraged industrial water recycling and investigations into the possibilities of major reuse of effluent in the Gaborone area, at the micro level of individual households and consumers, only limited official encouragement has been given to water conservation measures. This is surprising given the frequent references by government for the need for greater efforts to conserve this vital resource. In the National Policy on Natural Resources Paper No.1 (Republic of Botswana 1990), the recommended strategy for government action on water resources states the need for a wide ranging package of solutions in response to the growing pressure on water resources. These include "the possible introduction of incentives to encourage the collection of rainwater" and the need for research with "focus upon rainfall harvesting and water storage methods" as well as groundwater, effluent reuse, pollution prevention and interregional water transfers.

While considerable resources have been put behind research and feasibility studies regarding these other areas, Botswana does not yet seem to be taking water conservation in general and the direct utilization of rainwater in particular, sufficiently seriously. While the total quantity of rainwater collected at a household level or that saved by reuse such as using greywater for watering plants may not be that great in themselves, they have the highly positive spin off of conscientizing consumers to the importance of water conservation and discouraging wasteful use of communal or mains supplies.

The Government of Botswana has a unique opportunity to encourage widespread water conservation methods at the household level (particularly in high demand centres) due to its ownership of much of the countries housing stock through Botswana Housing Corporation (BHC). As the nations number one landlord and client of new construction the Government has an excellent opportunity to invest in the future by ensuring that designs for all new housing stock include specific water conservation measures in their design, such as rainwater tanks, opportunities for using greywater and landscaping designed to encourage the use of natural runoff for watering gardens, Figure 2. In addition, the incorporation of water saving devices such as low volume shower heads, dual flush toilet cisterns and spring load self closing taps for yard water supplies should also be included in future building projects.

In a study of rainwater catchment systems development, commissioned by the Botswana Technology Centre (BTC), Gould (1991), it was found that the construction of large rainwater tanks at large government buildings in Gaborone could yield water at a cost of P1.79/m^3 competitive with Water Utilities Corporation (WUC) rates and well below the long run marginal cost. It was also shown that the installation of relatively small 2m^3 tanks at all (16,034) residential housing units in Gaborone could potentially yield almost 14m^3 per household or a total of more than 220,000 m^3/year of rainwater with a value of around P500,000/year or P10,000,000 over the 20-year life expectancy of the tank. The value of the water from each tank being about P625 (at 1991 prices).

In rural areas and particularly remoter areas where provision of water to scattered households is far more expensive than in larger settlements the economics of rainwater collection is even more attractive, but here a government subsidy is essential to assist householders in meeting the initial investment costs. To some extent the current ALDEP water tank package is providing this possibility to rural households, but improvements in the design and its more active promotion are needed as recommended at the recent Workshop on Rainwater Catchment Systems Technology and Utilization in Botswana, Gould and Gurusamy (1993).

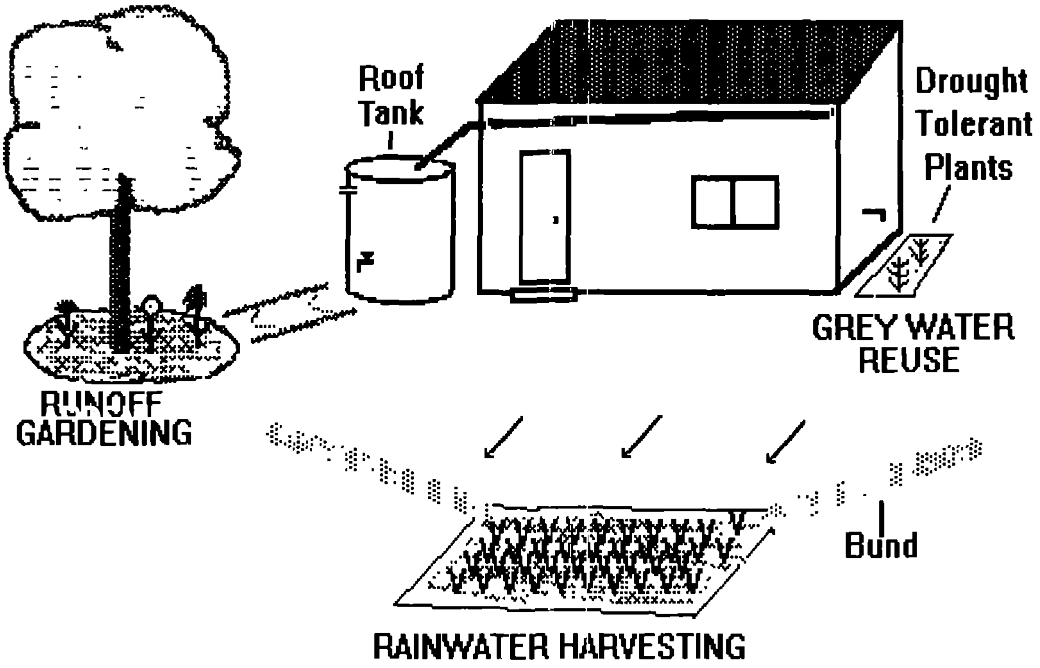

Fig. 2 Water Conservation Measures Appropriate for Households in Botswana

In addition to rainwater collection systems at individual households, there is considerable potential for utilizing rain and storm water runoff from institutions. The University of Botswana campus serves as a good example. The campus has an area of about 60 ha. or $600{,}000m^2$. About 50% of this is impervious being either paved of covered by roofed buildings providing a potential catchment area of around $300{,}000m^2$. Given that the mean annual rainfall is 535mm and assuming a runoff coefficient of 0.7 the potential mean annual collectable runoff is simply calculated as follows:-

Collectable Runoff = Rainfall X Catchment Area X Runoff Coefficient

$$= 0.535\ m \times 300{,}000\ m^2 \times 0.7$$

$$= 112{,}000\ m^3$$

The University currently consumes around 175,000 m^3 of water per year costing around P770,000. This potentially collectable runoff is equivalent to >64% of the current demand and an equivalent volume bought from Water Utilities would cost almost P450,000 annually. Although the cost of systems for the collection, storage and treatment of all of this rainwater runoff would probably not be cost effective when compared to the existing supply, the collection of some rainwater runoff in large surface and sub-surface tanks to provide supplementary water for watering plants, washing vehicles etc.. would almost certainly make good economic sense.

Apart from the physical inclusion of water conservation hardware at new Botswana Housing Corporation (BHC) housing projects and the retrofitting of existing housing stock, it is important to encourage public awareness and active participation through a carefully co-ordinated national campaign.

Lessons from South Australia

The State of South Australia has a climate and landscape very similar to Botswana particularly in the interior. Rainfall is low, seasonal and erratic with mean annual total s in the range from >800mm to <150mm, Temperatures and hence evaporation rates are high and greatly exceed precipitation. In response to the great scarcity of water the Government of South Australia, actively promotes a wide range of water conservation techniques including rainwater collection, drip irrigation systems, use of volume toilets and self-closing taps. In addition, the State Government also actively works to increase public awareness and educate consumers about various ways to reduce consumption, reuse/recycle waste water, and minimize garden watering needs through use of drought tolerant species and efficiently diverting runoff to trees and flowerbeds. The on-going water conservation campaign provides advice and free information to the public through the Engineering and Water Supply Department. The South Australian approach to water conservation provides an excellent model which Botswana could use as a basis for similar long-term water conservation strategy.

National Water Conservation Strategy

In order to effectively introduce widespread water conservation practices the measures outlined should be actively promoted and co-ordinated through the development of a National Water Conservation Strategy (NWCS). A small department with responsibility for this could be set up within the National Conservation Strategy, Dept. of Water Affairs or as part of a new Water Resources Council as proposed by BNWMP (1991). This department would be charged with raising public awareness regarding all aspects of water conservation and would lead a long-term campaign to promote and encourage this practice. The department should have sufficient resources to produce relevant materials, books, leaflets, posters, videos etc.. to promote its message. In addition small advertisements might be taken out in the press and jingles given on the radio. In particular schools should be targeted and water conservation included in the curriculum at various levels.The NWCS should also target industry to encourage it to recycle and reuse water where possible in addition to collecting rainwater runoff.

CONCLUSIONS

In addressing itself to the problem of meeting the rapidly growing water demands in Botswana over the period up to 2020 the BNWMP adopted a conventional demand oriented technical approach whereby future water demands were forecast and technical solutions to meet these forecasts then proposed. An alternative 'resource oriented' approach involving the introduction of active measures to control demand and encourage water conservation measures has not, however, yet been given serious consideration.

A new approach to water resource development in Botswana is thus proposed centred around a National Water Conservation Strategy (NWCS). Such a strategy would involve efforts to reduce, re-use, recycle and re-direct water so that existing resources can be utilized far more effectively. This would involve a variety of demand curbing measures including price control, reducing water pressure and restrictions (especially during droughts), and encouraging water re-use and recycling by both domestic and industrial users. In addition a wide range of water conservation measures including increased rainwater collection, runoff gardening and greater use of appropriate drought resistant plants, use of grey water and water saving devices also need to be encouraged.

While such a strategy would be very challenging to implement over the short-term, in the longer term it offers huge potential benefits to both individuals and the nation as a whole. If successful in reducing national water demand by just 10%-20%, a NWCS could help to ease the huge economic burden which will be imposed on the people of Botswana in order to meet and sustain the high levels of estimated future demand. Higher reductions in predicted demand could also help to ensure that the country remains more or less self-sufficient with respect to its water resource provision.

Allowing demand to continue to steadily rise unchecked could well result in the need to rely in future increasingly on water sources originating outside of Botswana's borders. This strategy carries with it a number of inherent risks with it; not only would it create a dependence on neighbouring states, but it would put Botswana at the mercy of deliberate or accidental pollution of upstream sources. It also would create the real possibility of conflicts over the use of shared water resources.

If the development of sustainable water resources in Botswana really is a national goal as stated in the National Conservation Strategy and the Water Master Plan, then the sooner a serious water conservation strategy is introduced the easier it will be to achieve.

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DROUGHT MANAGEMENT IN NAMIBIA 1992/93 WITH SPECIAL REFERENCE TO WATER SUPPLY AND THE USE OF PUBLIC AWARENESS CAMPAIGNS

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ABSTRACT

In April 1992 the Government of the Republic of Namibia declared a Drought Emergency as a result of the culmination of a series of poor rainy seasons. In order to cope with the devastating effects of the drought on the people the Government set up a National Drought Relief Programme to be managed by the National Drought Task Force. One of the key elements in the Task Force was the Emergency Water Supply Unit drawn from the Ministry of Agriculture Water and Rural Development.

This paper looks at the challenges in the Water Sector that faced Namibia and how that challenge was met, the organisation that was put in place to undertake the task of maintaining the supply of water to the hardest hit communities, the organisation's budget and its activities. Of particular note is the fact that the drought relief measures brought about a re-examination of the division of ministerial responsibility especially with respect to rural water supply. This has taken place against a background of transition from the provision of centrally controlled government services to more local and regional autonomy and decision making: a process which is on going. Many of the lessons that have been learnt have now been incorporated into the line management structures of the Department of Water Affairs, Namibia. This has placed it in a better position to handle future droughts without having to have recourse to the creation of additional organisations.

Of particular interest was the mounting of a public relations, awareness and education campaign as an integral part of the drought relief efforts. The principle aim behind this was to heighten people's awareness, to change perceptions and through education promote better understanding of the wise use of water. Details of the campaign, the media used and the material produced will be described and discussed.

BACKGROUND

Sandwiched between two deserts Namibia is the most arid country in southern africa. The scarcity of water concerns the vast majority of Namibians. The arid conditions had been exacerbated over the previous 4 years by below average rainfall culminating in the 1992/93 drought. Pasture had been severely affected, compounded by the effects of population growth and environmental degradation. Water resources were depleted due to an almost total lack of recharge. Rural water supply had been particularly hard hit.

DEMOGRAPHICS

The population of Namibia was 1,401,711 in 1991, 848,744 of whom are in the five northern districts. Of the total population, 67% live in rural areas, 764,115 in the five northern districts. Average total density is 1.7 persons per square kilometre.

Although classified as a middle income country (per capita income in 1989 was US $1,188) the income distribution is highly uneven, 55% of the population receive less than 5% of the GDP with a per capita income of US $63.

In the face of such poverty there is a heavy dependency on government to provide basic services at no cost. There is a perception that government owes this to the people.

NATIONAL DROUGHT TASK FORCE

In response to the drought situation of 1992 the Namibian Government established a National Drought Task Force to manage and coordinate relief efforts. Within this Task Force a special Unit to deal with water related issues was formed, the Emergency Water Supply Unit (EWSU). The primary purpose of EWSU was to secure water supply to drought affected communities, preferably by means which be incorporated into the water supply infrastructure e.g.

- Provision of new boreholes
- Rehabilitation of existing borehole supply points
- Extension of pipelines
- Construction of storage tanks
- Provision of water tanker services

At the outset is was realised that in order for the drought relief activities to be successful it would be essential for local communities to be fully involved and committed. This was a departure from the traditional approach adopted by the Department of Water Affairs in Namibia which made up the EWSU. In the past a top down approach had been adopted in which communities were not active participants. The new approach had its origins in the changed circumstances and social climate in post independence Namibia as well as the realisation that the most serious drought problems were being experienced in rural areas.

WATER COMMITTEES

Generally speaking the major urban centres were not drastically affected by the drought as there was a system of monitoring water supplies which enabled timely measures to be implemented. In rural areas none of this applied. In order to identify critical drought problems the knowledge and expertise of the local rural communities had to be mobilised. This was done through the formation and mobilisation of Water Committees. Members of the Water Communities were drawn from community leaders and other prominent members in local communities. These persons had the responsibility of identifying, receiving, evaluating and prioritising requests for drought assistance as well as recommending what measures were to be adopted. The committees were supported in their work by technical personnel seconded from the EWSU. Having decided upon what measures were to be undertaken actual implementation was in the hands of the seconded technical personnel, who had to report back to the Water Committees on progress.

In some cases it was not possible with either the available local resources or the expertise available to implement local relief measures. In such cases matters were referred via the EWSU central management committee to the Planning and Design Office or to the Emergency Groundwater Supply Unit. The central management committee performed a coordinating function as well as a supervisory one especially with respect to the control of the drought relief budget.

It must be said that the establishment of this drought relief structure was not without its difficulties. There was no prior legacy of formal regional structures through which communities could participate and cooperate with government. Government structures tended to be highly centralised and in the case of the Department of Water Affairs technically orientated. Few if any of those involved from the ESWU side had any experience or skills in community involvement.

RELIEF MEASURES

Initially when the first appraisal of the required relief measures was done, provision was made for the rehabilitation of 45 boreholes and the drilling and equipping of 40 new boreholes, for which US $3 million was budgeted. From the number of requests that poured into the water committees it became clear that the need for boreholes far outstripped the resources originally allocated. Cabinet made available additional funds, bringing total allocation to US $10 million.

The largest ever drilling programme in the country's history was embarked upon. Ten drilling contracts and five rehabilitation contracts were awarded, to run concurrently. This required a large input from the Department control and monitor progress. One of the contracts was for drilling 250 boreholes - the largest ever awarded in Namibia. These contracts did not include drilling work done by the Department of Water Affairs or by the International Medical Corps.

Communities also played a vital role in implementing drought relief measures. Especially in the central and eastern regions, willingness on the part of the communities to be involved in the implementation of the water projects was quite marked. Most of the excavations, pipe laying and backfill of the pipeline extensions as well as of water tank construction was done by the community members. This contribution enabled substantial cost savings to be achieved. This also helped the community members to start taking responsibility in the regulation of their water supply through local water committees that were subsequently formed.

In all by June 1993 the following had been achieved;

- 272 km of new pipeline had been laid
- 200 new offtakes on pipelines had been provided
- Over 400 boreholes had been drilled and installed. The average drilling success rate was approximately 70%.

- 31 water tankers had covered over 1 million kilometres delivering water to schools, clinics, and some of the most disadvantaged communities in rural areas.

LESSONS LEARNT

In many communities water storage facilities did not exist. Water tanks had to be provided and in this the EWSU was assisted by UNICEF and with a grant from the US Ambassador's Self Help Fund which augmented the number of tanks deployed. Seventy 5,000 litre water tanks were installed at schools. The EWSU provided a further 70 tanks for the same purpose. UNICEF funded the installation of 73 water storage tanks at various locations. Their support also covered the training of storage tank construction teams.

The provision of water tankers to deliver water free of charge to communities, although an appropriate relief measure, however, did tend to create dependence on the service. When the time cam for the withdrawal of the service strong adverse reactions were registered by the communities leading in some cases to the continuation of the services.

Mobilisation lead time to provide drought relief measures such as provision or rehabilitation of a borehole were found to be three months or longer. This was obviously too slow in the eyes of the drought affected victims. People often have the perception that once a request had been submitted a solution would follow within days and this lead to frustration and mistrust when not handled sensitively.

Some NGOs tended to act independently and would not coordinate their activities with the EWSU. This tended to create duplication and wasted effort. Furthermore, there was an unequal spread of NGO assistance over the country with some regions receiving more than others.

Other agencies and NGOs reacted too slowly to request for assistance and required lengthy application procedures which in some cases was so slow that the work had been completed before a response was obtain. Furthermore such agencies would not consider retrospective reimbursement for work done.

A number of requests for drought relief assistance by communities proved to be caused, primarily, by neglect. The needs were real and no action would otherwise have been taken. In some cases the EWSU had to respond to particular requests because pressure was brought to bear on it for certain actions to be taken. The lesson was that it was only by having a broadly based representation on Water Committees and insisting that all requests go through committees that such interference would be avoided.

The drought experience highlighted the need to set up a proper information database on rural water resources and supply. In the absence of this it was extremely difficult to evaluate the quantitative effects of the drought on the country's water resource and the result of recharge.

At the same time there was a need to asses the impact and effectiveness of the drought relief activities in the water sector as this has been neglected by other monitoring exercises. A comprehensive review must be done on an independent basis in order to provide objective feedback and clear evaluation.

The drought was instrumental in exposing the sorry state of the rural water supply installations throughout Namibia. Furthermore, the institutional arrangements for handling rural water supply needed strengthening and restructuring and that the entire national water sector should be under a single institution. The realisation led to the incorporation in a government rationalisation process that the water sector including rural water supply should be restructured under the Department of Water Affairs in the Ministry of Agriculture, Water and Rural Development.

Table 1. Donor and NGO input in the emergency water supply programme

DONOR	ASSISTANCE	VALUE
International Medical Corp.	**Drilling and installation of 40 boreholes in Erongo and Kunene.**	**R 1 700 000**
International Red Cross	**Rehabilitation of borehole installation and spring protection**	**R 500 000**
Government of Nigeria	**Drilling 25 boreholes in Kunene**	**R 1 500 000**
Grand Duchy of Luxembourg	**Provision of 6 Water tankers**	**R 2 500 000**
US Embassy	**Provision of six water bladders**	**R 40 000**
US Embassy: Ambassador's Fund	**Purchase of 70 water storage tanks**	**R 200 000**
Peace Corps (USA)	**Provision of 6 volunteers**	**R 300 000**
Voluntary Service Overseas (UK)	**Provision of 12 volunteers**	**R 100 000**
Oxfam Canada	**Drilling of 13 boreholes in Okavango**	**R 800 000**
Government of Canada	**Two Community pipeline projects**	**R 210 000**
UNICEF	**Purchase of 73 water storage tanks** **Expertise/materials to Media Office**	**R 200 000** **R 200 000**
SIDA	**Borehole support package**	**R 210 000**
	TOTAL	**R 8 460 000**

MEDIA OFFICE

A Media Office component of EWSU was also established - its task being twofold. Firstly, to inform drought victims that relief was available and how to request it. A further purpose being to publicise the efforts made to provide relief. This gave positive feedback to drought victims, donors and NGOs.

The second task was to create greater public awareness concerning use and abuse of water. There was a very strong belief that technical solutions would not be sustainable if there were not a concerted effort to bring about change in people's attitudes, practices, overcome ignorance and provide alternatives. Active community participation would be a key element. Whilst it was clearly recognised that this was a long-term goal, the drought situation created a sense of urgency and an opportunity to exploit the increased appreciation for this scarce resource.

Rapid rural assessments of water issues indicated that a holistic approach should be adopted. In designing such a campaign, responsibility for water awareness could not be fragmented between different ministries. An integrated approach was adopted, linking water, health and sanitation to address issues of concern.

Personnel from the Department of Water Affairs Namibia were seconded to the Media Office on a part-time basis, while UNICEF made available a communication specialist.

INFORMATION CAMPAIGN

The first step of the campaign was to publicise the fact that drought relief was available. This was done through the various language services of the national broadcasting (NBC), while secondary support was given by newspapers. Posters were used later to provide a more permanent source of information to communities.

Thereafter, information was generated to keep the public informed about what was being done. The Media Office made these details available rather than relying on the mass media's own efforts. This proactive approach was very important initially as it created confidence that something was being done.

These activities not only focused attention on water and the drought, but also created a conducive environment for public awareness.

PUBLIC AWARENESS

The awareness campaign had to accommodate many complicating factors including regional culture and biophysical diversity, the literacy level as well as the accessibility of target audiences. The primary target became children between the ages of 10 and 15, for a number of reasons. School attendance and literacy rates were higher, and there would be carryover factor to other members of households. The younger generation would also be the adults and leaders of the future.

Other groups addressed included the urban rich, the urban poor, and rural communities with access to some means of formal water supply, e.g water points. The message, language, and media had to be chosen to suit each target group.

An awareness strategy was devised, based upon proposals from two firms of public relations consultants. This strategy was modified as experience was gained. A less advertising orientated approach and a more comprehensive community orientated strategy was adopted. This was the basis of an integrated information, education and communication campaign. Much emphasis was put on the use of radio, 95% of the population having access to one. Radio was reinforced by pamphlets and posters propounding the same messages and distribution through schools, clinics, churches, government offices and non-governmental agencies. Television was little used as only a small, urbanised, percentage of the population had access to it.

The campaign as it finally emerged can be categorised as follows:

Attention Grabbing Phase

- *Television adverts*
- *Radio messages*
- *Musical jingle*

Popularisation Phase

- *Generic posters and pamphlets*
- *addressing topics of concern aimed at urban and rural populations*
- *Cartoon comic strips targeting children and addressing topics of broad concern*
- *Radio 'Soap' serial targeting children*

Specific Concerns Phase:

- *Rapid rural assessment of water, health and sanitation issues*
- *Pamphlets and posters specific to identified issues (including protesting)*
- *Radio adverts to support the pamphlets.*
- *Videos to support pamphlets, for schools.*
- *Radio programmes to discuss specific topics for adults*

- *Comic books and worksheets on specific topics for children*

- *Regional workshops to agree on implementation strategies.*

In the last phase conscious efforts were made to network with other organisations, both government and non-government, active in water related activities. This was done on an informal basis with the Media Office taking the lead. Concerns and issues raised by them were incorporated into the material developed where possible, leading to the production of integrated material, cutting across sectoral boundaries.

Finally, regional workshops were organised. These were seen as the key to the success of the effort to change attitudes and practices. The purpose of the workshops was to mobilise communities to manage the improvement of their own water health and sanitation situation. It was up to the community leaders to formulate strategies which they could implement and for the Media Office, in conjunction with UNICEF to assist and support such initiatives. The people themselves must want change rather than be dictated to that they must change.

CONCLUSIONS

Whilst public awareness cannot overcome a drought it can mitigate the effects through the promotion of the judicious use of water. It became clear that as a result of the campaign there was a much greater degree of water awareness among all sections of the Namibian public. The information campaign had been particularly successful. Especially so given that the material was generated without having full-time staff. Had this been the case much more would have been achieved.

A number of lessons were learnt from the public awareness campaign. As this was the first effort of its kind experience was gained as the work progressed. The decision to use PR companies to advise and design an awareness campaign was not successful as they were operating outside of their own expertise.

The use of especially radio in a variety of formats proved to be very successful. The multifaceted approach, the use of radio, printed material and workshops to mutually support the messages being given was particularly important in ensuring wide audience coverage.

The campaign in its final form relied heavily on the co-operation and assistance of many organisations and ministries for its successful implementation. This in itself was a potential problem area. But the initiative had been welcomed by many and demonstrated that an integrated approach can work.

CHANGING SETTLEMENT PATTERNS AND THEIR IMPACT ON WATER AND OTHER SERVICE PROVISION

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ABSTRACT

The dynamics of population and settlement pattern change in the past 10 to 15 years has raised a lot of interest in government circles. Many settlements which were only lands areas or cattle posts have developed into villages and some even into sizable settlements. What is somewhat alarming is that the establishment of new settlements has gone beyond the control of the Land Boards which have the mandate over land allocation and land use. These developments have had a negative impact on some service sectors of the economy such as water, health and education, although with the exception of agriculture for which the trend has had a generally positive impact as far as agricultural production is concerned.

The water sector is the sector hardest hit by this development since almost all human activity depends on this resource. Not only is water of absolute necessity, but it is also scarce. On the establishment of a new settlement the very first service that is requested is the provision of potable water. For many years, new small settlements were provided with reticulate village water supply systems even when they were technically too small too qualify. The basic requirement for the provision of a water supply system being a population of at least 500. In the past a number of communities have tried to acquire education and health facilities in first knowing that this would help to force councils to then provide water. It is unfortunate that political representatives have been used to lobby for village water supply systems in council resulting in water being provided to less deserving settlements. It is of growing concern how long this is likely to go on for and whether the maintenance and financing of such supplies will be sustainable.

This paper addresses the issue of changing settlement patterns and the resulting impact on the provision of water and other services. It discusses the problem of water provision in the lands areas, cattle posts and villages and examines reasons for the dispersion of population to small settlements. Possible solutions that would assist district councils in addressing the issue of changing settlement patterns and the impact on water provision are also presented.

INTRODUCTION

Settlement planning is a subject area that focuses on the function and pattern or shape of settlements, land use within and outside the settlements, house types and building materials, relationships between settlements of different sizes and the changes in settlement patterns over time. There is an increasing interest in the growth and change of rural settlements. This is in realisation of the fact that settlements are not static but continually changing. This is particularly true of Botswana whereby the set up in our rural areas is changing slowly from the tripartite settlement pattern with some of the lands areas becoming permanent settlements characterised by the establishment of permanent and durable residential structures. The change in our settlement pattern is not without implications on all sectors of the economy, particularly the service sector. The main purpose of this paper is to look at the changing nature of Botswana's Settlement pattern. It will also look at how these changes have affected other sectors of the economy, particularly the service sector, and the response of central and local government to these changes. It is hoped that the paper will make modest contributions towards possible options that government can take in response to issues rising from the changing settlement pattern in Botswana's rural areas.

Historically, Botswana's settlement patterns are generally characterised by an unusual tradition of mobility. According to Botswana tradition, people lived in 3 types of settlements. An individual family had a residence in a village, a focal point of tribal life. In the adjacent land the average Motswana family ploughed and grazed their stock. But over time due to population pressure and land exhaustion, the chiefs allocated the adjacent areas for cultivation, what is formerly called Lands areas, and areas further beyond were allocated as cattle posts for the raising and grazing of cows. There was traditionally a seasonal migration between the 3 homesteads during the year for ploughing and raising cattle and the chief had to a certain degree exercise some authority over these movements. The Chiefs used to punish those who stayed at the lands after harvest. The lands and cattle posts were unlike the village, regarded as temporary seasonal settlements to the extent that there were no services and infrastructure as found in the villages. The residential structures, locally called "mekgoro" or "disowa" were made of local materials such as mud and grass, and no sanitation facilities and portable water could be found in the lands areas.

Although the tripartite settlement pattern is still relatively predominant, even now, changes have been noted as far back as the 1970's. Stephens (1975) noted that "there is evidence of some permanent settlement at the lands, as the power of the tribal authority wanes." During the seventies, Silitshena (1976) also noted that the tripartite system appears to be changing as individual households settle at either the lands or cattle posts, leaving their homes in the villages to disintegrate. He quoted the results of an agricultural survey of 1972 which noted that " the tripartite system of having one dwelling each at a village, lands and cattle posts has broken down to the extent that it was found that a small majority of households had a dwelling at one place only." The 1971 Census (CSO 1971) did pick up this trend of people increasingly living at the lands. This has an implication on the service sector of the economy because district councils have been compelled to bring services to these new settlements. Such services include water, schools, health facilities and other extension services.

WATER PROVISION

Water is a basic human need. In Botswana, water takes a very precious and important place in human life because it is one of the resources which, nationally, is in relatively short supply. In the absence of surface water and perennial rivers in many parts of Botswana, the provision of water is a relatively expensive exercise because most of it is pumped from underground. As such the development and utilisation of our water should be sustainable.

The installation, operation and maintenance of water supply networks in rural villages is the responsibility of both the Department of Water Affairs and the Ministry of Local Government, Lands and Housing. This function is decentralised in such a way that each district council has a water unit which applies a policy of paid up services to the public. The design, financing and execution of these rural water supply networks is coordinated by an engineer in the Ministry of Local Government, Lands and Housing.

From a settlement planning point of view, the problem faced by government currently in the provision of water services is two fold. First, it seems there is a gap in the institutional arrangements for the provision of water for the dispersed population in the cattle posts and lands areas. Secondly, there is a problem related to a rapidly increasing number of settlements requesting for village water supplies to the extent that the Ministry of Local Government, Lands and Housing cannot cope with the demand. These two problems are inter-related such that the first issue influences the second one because in the absence of a programme to provide water to lands areas, some lands areas are requesting for services under the wrong programme. However, some of the lands areas have already been turned into permanent settlements with people residing in them throughout the year.

WATER PROVISION TO LANDS AND CATTLE POSTS AREAS

According to the 1981 Population Census, 37% of the country's population lived in scattered and thinly populated settlements. The economic base of such settlements are arable crop production and livestock breeding. This particular group of settlements is formerly not catered for in water provision programmes. As rightly mentioned in the Lands Area Water Supply Study (Executive Summary), *"the water requirements of the towns and villages are currently dealt with by the Central Government and District Authorities (i.e. DWA, MLGLH and Councils) through formal policies and programmes such as the Rural Water Supply Programme. No such policies have so far been developed for the scattered rural population which constitutes a district problem, because of its dispersion and seasonality",* LAWSS (1991). Although the Ministry of Agriculture to an extent provides water to this population through ALDEP, the Small Dams Unit and the Irrigation Unit, there is no co-ordinated domestic water supply programme for the lands and cattle posts areas. It was in light of this problem that the Lands Area Water Supply was commissioned by government in 1992.
Some of the settlements which fall under this category of scattered rural population have been provided with complete village water supply systems before mainly through motions passed in Council. Districts such as Southern, Central and Kweneng have been compelled to provide water and other services such as schools and health facilities. The National Water Master Plan, 1991 (Volume 3, pg.2-23) noted this problem - "water is relatively scarce in the lands areas, consequently an increase in the number of settlements, contrary to the National Settlement Policy, has significant implications for the provision of infrastructure".

THE DISPERSION OF RURAL POPULATION INTO SMALLER SETTLEMENTS

The Ministry of Local Government, Lands and Housing is, as stated, confronted with a problem of a marked increase in the number of villages which are requesting for village water supplies. Since independence, there has been a growing tendency for the number of villages to increase as many lands and some cattle posts areas are converted and designated villages.

Reference is made to Tables 1 and 2 in Appendix 1. It is very clear from Table that a lot of settlements which during the 1971 Census were small and not considered as villages grew three or more in size between 1981 and 1991 Census, such settlements were either lands areas or cattle posts. There are in addition some villages which were established on virgin land such as Xade, Dakar, Sechele, Kgari, Matshelagabedi. The Draft NSP document, acknowledged that Government Policy was not very clear on the definition and control of settlements and as a result unplanned settlements continued to spring up in wildlife, livestock grazing, forest and lands areas. Many districts experience the phenomena of abrupt village establishment without due regard to the land uses in the area, availability of water and any other environmental factors. More often than not such settlement development has led to the rush to provide services such as water, health facilities and schools in the absence of adequate needs assessment and likely consequences. One of the obvious results of this is an imbalance in service provision characterised by shortages of services (i.e. under provision) in some settlements and over servicing in areas where the population is too small for the type of services that are provided. Some District Councils have had to close schools which have very few students, like in the case of Two Rivers which had a school with only seven students. Although the central District Council resolved to close the school, the fact remains that the service exists and remains a white elephant. The water sector is perhaps the single most affected and strained service sector. As these new settlements arise, the first service they usually request for is water. Some of these settlements have a couple of families because most of them are break-away settlements from established villages, becoming permanent settlements at the lands or cattle posts. With time, some people realised that if they got funds to build a school, government would be compelled to provide water.

The dispersion of the rural population into smaller settlements away from the traditional villages can be attributed to the following factors:

(i) The Introduction of the borehole technology opened up a lot of areas which were previously not habitable due to lack of surface water. A lot of settlements have therefore been established in what was formally wildlife or livestock ranching areas. Land use conflicts have emanated from such settlement development.

(ii) Government policies from various sectors have contributed to the establishment of settlements at the lands and cattle posts. These include agricultural policies which encourage people to stay at the lands in an effort to increase output in arable farming. It also seems that the local people have realised that settling at the lands and cattle post areas enables them to manage their agricultural activities better. The wildlife sector has also through the development of game ranching schemes and other projects encouraged development of settlements such as the one at Kedia. Other Government policies that encourage settlements include the Remote Area Dwellers Programme which has actually established a lot of settlements in areas not meant for human activity. Many more examples can be identified under various sectors of Government.

iii) The appointment of headman contributed to the establishment of many small settlements as villages. Communities appointed headmen which were approved by the tribal authority. Councils used to take any settlements with a headman as a village and as a result with pressure from such communities, facilities such as schools and clinics were provided. This strengthened the growth of such settlements and consequently brought disintegration to existing nearby villages which were long established.

(iv) The land rights as described in the Tribal Land Act executed by the Landboard have also contributed to the problem of establishment of settlements anywhere by encouraging Batswana to settle anywhere they want. The erosion of the powers of the chief over the control of land removed a key factor encouraging nucleated settlements. This coupled with the issuing of trade licences for any place has led to the establishment of commercial services anywhere. This encouraged settlement proliferation because people have a tendency to settle around commercial establishments such as general dealers, bottle stores etc. This is common particularly along major roads such as the Gaborone-Francistown road.

(v) Local policies have directly and indirectly affected settlement pattern in Botswana. Some settlements have been set up with the influence of some prominent people in society. Others are a result of conflicts within the community sometimes over issue of headmen or chiefs as to who has the ruling power. The influence of some local Councillors and Members of Parliament in council has led to the provision of services to villages which did not deserve the facilities as yet.

(vi) Population pressure is also a contributing factor that has led to the permanent settlement in the lands and cattle post areas.

Table 2 in the Appendix shows the general demographic characteristics of the settlements which requested for village water supplies in 1993. The Ministry of Local Government, Lands and Housing under the National Settlement Policy (NSP 1992) has provided a guiding criteria that no settlement which is not a village shall be provided with any services including water. A village is defined as follows;

> "A recognised gazetted village is a settlement with a minimum population of 500, and more than 15 km away from the main or parent village, have a tribal authority, permanent water source, capable of supporting a small commercial/industrial business on a sustainable basis, outside National Parks and Game Reserves, preserved fertile arable lands; forest reserves and environmentally sensitive areas e.g. Okavango Delta Area".

SUMMARY AND CONCLUSIONS

In summary, given the issues already discussed above, one would wonder if the development of our rural water supplies is sustainable. The cost of the village water supply systems in the individual villages is fully financed, maintained and upgraded by the government. The cost for village water supply system to government varies from village to village mainly because there are significant economies of scale. It is much more expensive to provide water to a very small village. The more people being served the cheaper. The rationale behind a significant proportion of available funds for rural water supplies going towards villages of a relatively small population is questionable. Some of the villages do not even have a good economic base that would make the development of services sustainable. It is worth noting that not much can be changed on developments done in the past such as settlements with a population of below 500 with village water supply. More settlements like that will still be provided with water just because education and health facilities already exist. Nonetheless there needs to be a complete turn around in this area of provision of rural water supply to small settlements. This can only happen with supporting changes in some government policies and programmes. These include the following:

(a) That government finalises and adopts a strategy for the sustainable development and provision of drinking water in the lands and cattle post areas.

(b) That land use plans be prepared or revised for each and every area to provide guidance to the development of land for various uses. These land use plans should be gazetted and legally binding. Such a move would assist to curtail the problem of the establishment of settlements anywhere without due regard to land uses and natural resource capability.

(c) That district settlement strategies be prepared urgently to guide the provision of infrastructure for various sectors such as water, health, education, etc. This will ensure that any dispersion of growth and development is pursued with a comprehensive policy of decentralisation.

(d) That all the plans be prepared in close coordination with the water sector, following the National Water Master Plan and other Regional Water Schemes.

(e) That location of services strictly follows the definition of a village. Thus no settlement which does not qualify to be a village should be given any services such as water, schools and health facilities.

(f) That those settlements which deserve to be provided with village water supplies <u>but</u> are very close to a parent village should if technically feasible be connected.

(g) Grouping of settlements should be considered for the purpose of providing services, particularly in cases where settlements are very close to each other.

(h) In cases whereby settlements have a population far less than 500 but were provided with village water supply system, councils should not consider upgrading the system <u>but</u> just maintain it. Money for upgrading should be kept for more deserving villages.

(i) Those settlements already having other services like schools and health facilities should be provided with village water supply systems. However they should be provided with the minimum standard of village water supplies.

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APPENDIX 1

TABLE 1 POPULATION OF SMALL SETTLEMENTS IN 1971, 1981 AND 1991

NAME OF SETTLEMENT	POP.IN 1971	POP.IN 1981	POP.IN 1991	POP. IN 1971-1981	% IN 1981-1992
Ngwaketse (Southern District)					
Lotlhakane	213	884	2345	315.0	165.2
Kgomokasitwa	299	838	1186	180.3	41.5
Sesung	181	695	607	284.0	(-12.7)
Magotlhwane	272	661	1014	143.0	53.4
Maokane	140	653	614	366.4	(-3.3)
Tshidilamolomo	241	549	651	127.8	18.6
Sekoma	150	490	599	226.7	22.0
Leporong	276	461	558	67.0	21.0
Morwamose	180	398	505	121.7	26.9
Lekgobotlo	204	389	790	90.7	103.1
Keng	78	387	625	396.2	61.5
Sese	37	370	1023	900.0	176.5
Mokgomane	186	359	600	93.0	67.1
Metlobo	96	341	644	255.2	88.9
Tsonyane	-	304	515	-	69.4
Mokhomma	-	295	551	-	86.8
Lotlhakane	-	-	928	-	-
Segwagwa	32	278	599	768.7	115.5
Lerolwane	60	115	573	91.7	398.3
Kgalagadi District					
Khuis	213	490	595	130.0	21.4
Lokgwabe	300	866	1036	188.7	19.6
Kolonkwaneng	240	415	578	72.9	39.3
Bray	135	269	769	99.3	185.5
Kokotsa	-	-	844	-	-
Kweneng District					
Gamodubu	274	934	1116	240.9	19.5
Sojwe	250	662	991	164.8	49.7
Dutlwe	273	645	767	136.3	18.9
Takatokwana	160	592	1112	270.0	87.8
Lephephe	256	481	534	87.9	11.0
Metsemotlhabe	50	395	1763	690.9	346.3
Mmanoko	-	382	506	-	32.5
Maboane	201	315	547	56.7	73.7
Malwelwe	-	318	794	-	149.7
Ngwane	101	141	503	39.6	256.7
Moshaweng	209	327	650	56.5	98.8

<u>Kgatleng</u>					
Pilane	79	179	541	126.6	202.2
Matebeleng	128	386	599	201.6	55.2
<u>Central District</u>					
Lesenepole	256	965	1317	286.0	36.5
Mogapinyana	129	596	870	362.0	46.0
Mogorosi	253	554	963	119.0	73.8
Seolwane	121	521	935	330.6	79.5
Mmashoro	238	476	962	100.0	102.1
Topisi	124	339	623	173.4	83.8
Radisele	115	742	1256	545.2	69.3
Gojwane	-	-	619	-	-
Malaka	-	-	1118	-	-
Lechana	-	100	508	-	408.0
<u>Central Boteti District</u>					
Mmadikola	-	660	646	-	(-2.1)
Makalamabedi	263	537	884	104.2	64.6
Kedia	-	-	619	-	-
<u>Central Mahalapye</u>					
Mmutlane	-	720	822	-	14.2
Kudumatse	279	635	805	127.6	26.8
Maape	130	601	885	362	47.3
Shakwe	242	507	506	109.5	0.2
Dibete	-	251	753	-	200.0
<u>Central Bobonong</u>					
Semolale	248	1018	874	310.5	(-14.4)
Kobajango	239	855	1087	257.7	27.1
Mabelwe	360	696	1011	93.3	45.3
Mabolwe	112	519	572	353.4	10.2
Mathabaneng	-	-	625	-	-
<u>Central Tutume</u>					
Dukwi	-	1407	2509	-	78.3
Dakgwi	186	1023	1279	468.3	25.0
Marapong	-	951	1393	-	46.5
Mosetse	234	892	1451	281.2	62.7
Changate	127	785	1137	518.1	44.8
Shashe-Mooke	290	709	1451	144.5	104.7
Chadibe	-	539	742	-	37.7
Matsitama	135	503	770	272.6	53.1
Makobo	-	358	756	-	112.2
Dzoroga	-	354	626	-	76.8
Barotsi	-	636	818	-	28.6
Mokubilo	-	279	667	-	139.1
Nshakashogwe	239	147	1033	(-38.5)	602.7
Zezuru	-	463	500	-	8.0
Goshwe	-	768	799	-	4.0

North East District					
Mapoka	180	1558	1584	765.6	1.7
Tati	206	1390	2402	574.8	72.8
Tsamaya	210	1246	1540	493.3	23.6
Mosojane	-	1202	1249	-	3.9
Ramokgwebana	264	1087	1353	311.7	24.5
Moroka	253	988	1138	290.5	15.2
Siviya	156	952	1232	510.3	29.4
Mulambakwena	112	824	742	635.7	(-10.0)
Jackalas No.2	117	822	1039	602.6	26.4
Gambule/Butali	-	687	700	-	1.9
Letsholathebe	287	670	719	133.4	7.3
Gumare/Mbalambi	-	613	998	-	62.5
Kalakamati	267	585	678	119.1	15.9
Kgari	-	535	688	-	28.6
Sechele	-	534	606	-	13.5
Tshesebe	272	524	1145	92.6	118.5
Matshelagabedi	-	448	1295	-	165.4
Masingwaneng	230	445	559	93.5	25.6
Mambo	215	364	570	69.3	56.5
Shashe Bridge	-	-	601	-	-
Ngamiland District					
Toteng	246	565	507	129.7	(-10.3)
Shorobe	265	539	758	103.4	40.6
Sepopa	298	466	806	56.4	73.0
Tubu	166	331	508	99.4	53.5
Ghanzi District					
Charles Hill	224	390	996	74.1	155.4
Dekar	-	318	627	-	97.2
Xade	-	303	528	-	74.3
Chobe District					
Kachikau	243	364	516	49.8	41.8

SOURCE: **Department of Town and Regional Planning and Central Statistics Office**

TABLE 2 VILLAGES THAT REQUESTED WATER SUPPLY SYSTEMS IN 1993

DISTRICT	NAME OF SETTLEMENT	POPULATION IN 1981	POPULATION IN 1991
KGALAGADI	Maleshe/ Letlhopi		213
	Hunhukwe		356
	Ukhwi		311
NORTH WEST	Xamakao		245
	Mogotho		60
	Etsha 1		340
	Eretsa		286
	Lesoma		231
SOUTH WEST	kgale farm		16
	Maboane		15
	Marathadiba		28
GHANZI	Metsimantsho		144
	Makunda		200
	Metsimantle		167
KGATLENG	Khurutse		114
	Bodungwane		97
	Dikgonye		241
NORTH EAST	Dukwi		133
CENTRAL DISTRICT	Motshegaletau		80
	Sepako		366
	Manxutae		289
	Jamakata		338
	Jamakala		127
	Kutangore		261
	Lepashe		136
	Taupye		22
	Tobela		29
	Moralane		20
	Mokgenene		195
	Tewane		507
	Mokobaxane		614
	Nthane		469
	Mokobilo		668
	Mmakgama		51
	Khwee		158
	Two-River		133
	Khumega (Xhumaga)		397

SOUTHERN	Motshentshe Ditlharapa Dikhukung Phiring Sheepfarm Dipotsane Mogojwegojwe Diabo Betashankwe Bikwe Polokwe Seherelela Khonkwa Mohuduhutswe		196 274 340 75 312 176 400 377 148 149 319 231 225 75
KWENENG	Dikgatlhong Mmanoko Kotolanome Maboane Malwelwe Ngware Sesung Monwane Metsebotlhoko Mantshwabisi Kubung Ditshukudu Mogonono		157 505 365 567 794 512 774 14 295 375 653 424 240

Source: Department of Town and Regional Planning, Engineering Unit MLGLH and CSO

PROTECTION OF WATER RESOURCES AGAINST POLLUTION BY VULNERABILITY MAPPING IN BOTSWANA

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ABSTRACT

Botswana is a semi-arid country with very little groundwater recharge. However, groundwater is a major water resource for domestic, industrial and agricultural use. Therefore, there is an urgent need to ensure that it is of good quality by protecting it against pollution sources such as landfills, pit latrines, industries and filling stations. Better protection from uncontrolled dump sites can be achieved through proper siting for waste disposal in respect to water resources.

The production of vulnerability maps is regarded as an initial step towards the selection of areas for safer waste disposal, i.e. in regions which groundwater is less susceptible to pollution. Potential landfill sites can then be identified within these pre-selected areas for detailed investigations. Vulnerable locations e.g. unconfined aquifers, rivers, dams and deltas have to be avoided.

An ongoing groundwater vulnerability assessment project which started in June 1993, employs a rating system based on recharge, soils and (hydro)geological aspects. Infiltrating rainwater is the sole means of transport of pollutants into the groundwater system. The time of migration is a function of the amount of groundwater recharge, the thickness of strata overlying the groundwater body, and the properties of soils and rocks.

The Geological Survey Department, in co-operation with the Federal Institute for Geosciences and Natural Resources, Germany, is preparing a 1:1,000,000 groundwater vulnerability map for the whole country as well as detailed 1:50,000 maps for up to 18 selected towns and villages. These will serve as guidelines in management processes such as land allocation, landuse planning, water supply development and in selecting safe sites for waste disposal. The mapping exercise commenced in Lobatse at a scale of 1:50,000. This paper presents some results of this mapping where vulnerability is differentiated into four classes. Lobatse water resources are indicated as well as alternative sites for waste disposal. The prepared maps are of a reconnaissance nature and are based on information from existing geological and hydrogeological reports and maps, soil maps and data from borehole logs.

INTRODUCTION

Botswana is a semi-arid country with very limited water resources and furthermore, these resources are endangered by pollution. One of the core problems for sustainable water protection is the insufficient waste management in general and the uncontrolled disposal of waste in particular. In June 1993 a Botswana-German Technical Co-operation project was established to tackle these problems. It covers 2 projects : a waste management project operated by a team of national Conservation Strategy (NCS) and Gesellschaft Für Technische Zusammenarbeit (GTZ). The other project deals with water protection operated by a team of the Department of Geological Survey of Botswana (DGS) and the Federal Institute for Geosciences and Natural Resources, Germany (BGR). This paper focuses on the protection of water resources by preparation of groundwater vulnerability maps at a scale of 1:1,000,000 for the whole country as well as detailed 1:50,000 maps for most of the towns and major villages. Foster et al. (1988) defines vulnerability as the sensitivity of an aquifer to being affected by imposed contaminant loads. The idea is to demarcate regions on which groundwater is highly vulnerable to pollutants and those areas where groundwater is better protected by the overlying strata.

The vulnerability maps are compiled for use by planners in District and Town Councils, as well as by scientists in the University of Botswana, in Government agencies, and consulting companies. The map of scale 1:1000,000 aims furthermore at raising public awareness for groundwater protection and can be used for teaching aspects of environmental science at secondary and tertiary schooling level.

The Department of Water Affairs (DWA, 1993) produced reports on the protection of major wellfields and dams in Botswana. The present study expands the same subject and uses a German approach to vulnerability mapping. Additionally, potential areas for proper waste disposal sites will be identified.

APPROACH TO VULNERABILITY MAPPING

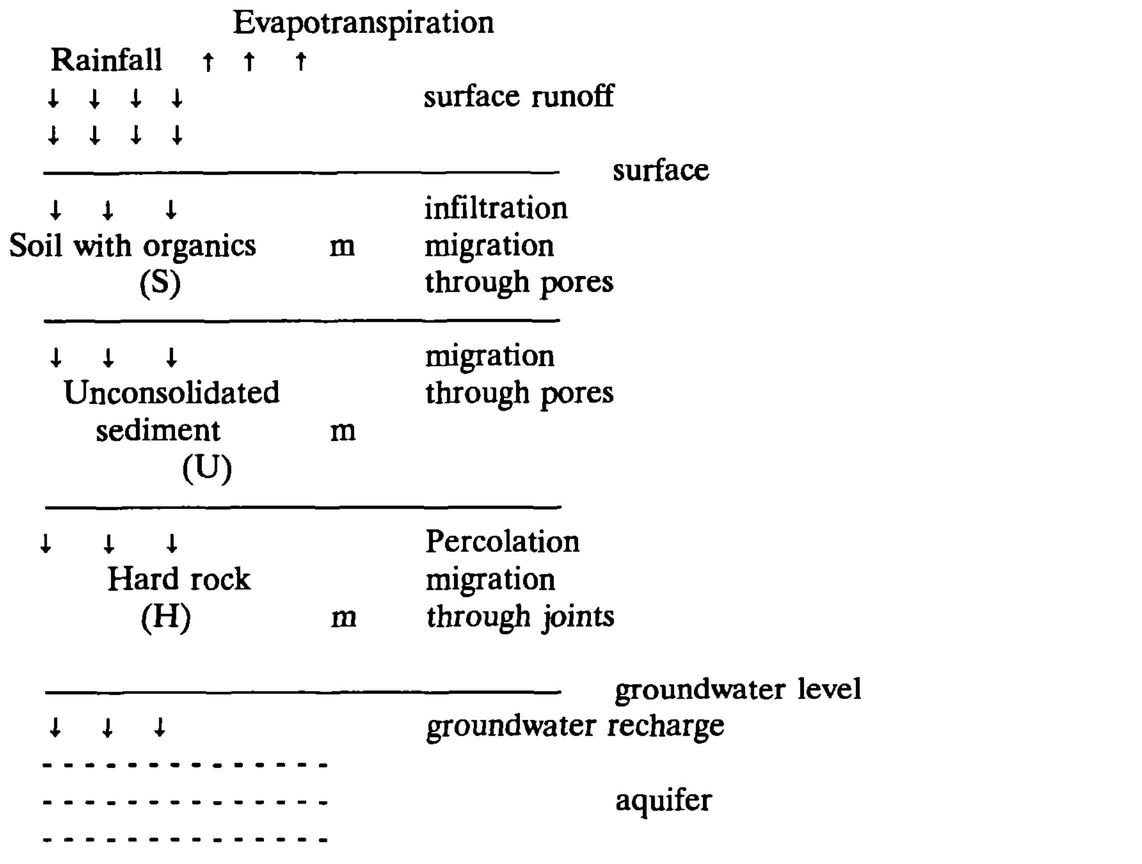
The scheme used for vulnerability mapping is based on a rating system developed by the State Geological Surveys in Germany (draft 1992) and uses the parameters presented in Table 1 and Figure 1. The overall criteria of groundwater protection is the migration time of polluted water from ground surface to the groundwater level (Table 1). Attenuating capacities of the aquifer are not considered in this rating system because aquifer properties cannot prevent but only absorb, confine and dilute contaminants.

Table 1 Classification of groundwater protection/vulnerability

Protection	vulnerability	rating	percolation time
very low	extreme	< 500	< 1 month
low	high	500 - 1 000	1 month - 3 years
moderate	moderate	1 000 - 2 000	3 - 10 years
high	low	2 000 - 4 000	10 - 25 years
very high	negligible	> 4 000	> 25 years

Based on the migration time, groundwater vulnerability is graded in 5 classes ranging from 0 to 4000. The vulnerability is classified as negligible in the event that pollutant will reach groundwater after 25 years. Time of migration is regarded as a function of the amount of groundwater recharge, the thickness of strata overlying the groundwater level, and the properties of soils and rocks, as shown in Fig.1.

The assessment of the rating factors of soil, sediments, rocks and groundwater recharge is described in the referred paper of the State Geological Surveys in Germany (in press, 1994). Groundwater recharge in Botswana is less than 100 mm/a and therefore calculated with a factor of 1.75, whereas groundwater recharge in a humid climate with a rate of 300 to 400 mm/a is calculated with a factor of 1, as shown in Table 2.



The rating system of groundwater protection is calculated according to the equation:

$$P = (S \times m \times W) + (U \times m \times W) + (H \times m \times W) + C$$

where P= Groundwater Protection
S= Soil
U= Unconsolidated sediments
H= Hard rock
m= thickness of strata
W= Groundwater recharge
C= Confined aquifer

Fig.1 Migration of seepage water within the strata above groundwater.

Table 2 Rating system for seepage water based on the groundwater recharge (factor W)

Groundwater recharge (mm/a)	Factor W
< 100	1.75 (Botswana)
100 - 200	1.5
200 - 300	1.25
300 - 400	1.0 (Germany)
> 400	0.5 (tropical area)

VULNERABILITY MAPPING IN THE AREA AROUND LOBATSE

This paper gives the first results of vulnerability mapping at a scale of 1:50,000 in the area around Lobatse, where the project began mid-1993. The map is based on data of the Geological Map 1:125,000, Sheet No. 2525B with report (Key 1983), the Soil Map of Botswana 1:250,000, Lobatse Sheet (1989) with explanations by Mafoko (1990), the Hydrogeological Map 1:500,000 (1984) and the Groundwater Resources Map 1:1000.000 (1987).

Additionally borehole data of the archive in the DGS, Lobatse, were used to get information about the present groundwater conditions, like depth of water level, water quality, and type of aquifer. Boundaries of wellfields protection zones were obtained from the Lobatse Wellfield Report (DWA 1993). Figure 2 shows a portion of the Lobatse vulnerability map. The map displays 4 classes of groundwater vulnerability: extreme, high, moderate and low.

The field of extreme vulnerability covers the Lobatse valley, where the important Lobatse aquifers are located. The aquifers are in karstic, highly permeable dolomite of the Precambrian Transvaal Supergroup, which are extremely sensitive to pollution from the surface. The dolomite outcrops in this area and therefore the aquifer is poorly protected by overlying strata. This aspect shows the necessity that pollutants should be kept away from this high risk area.

Further from Lobatse to the west the vulnerability sequence passes from extreme over high to moderate and low. Areas of high groundwater vulnerability are at the foot of the hills situated directly west of Lobatse town, where groundwater protection is more

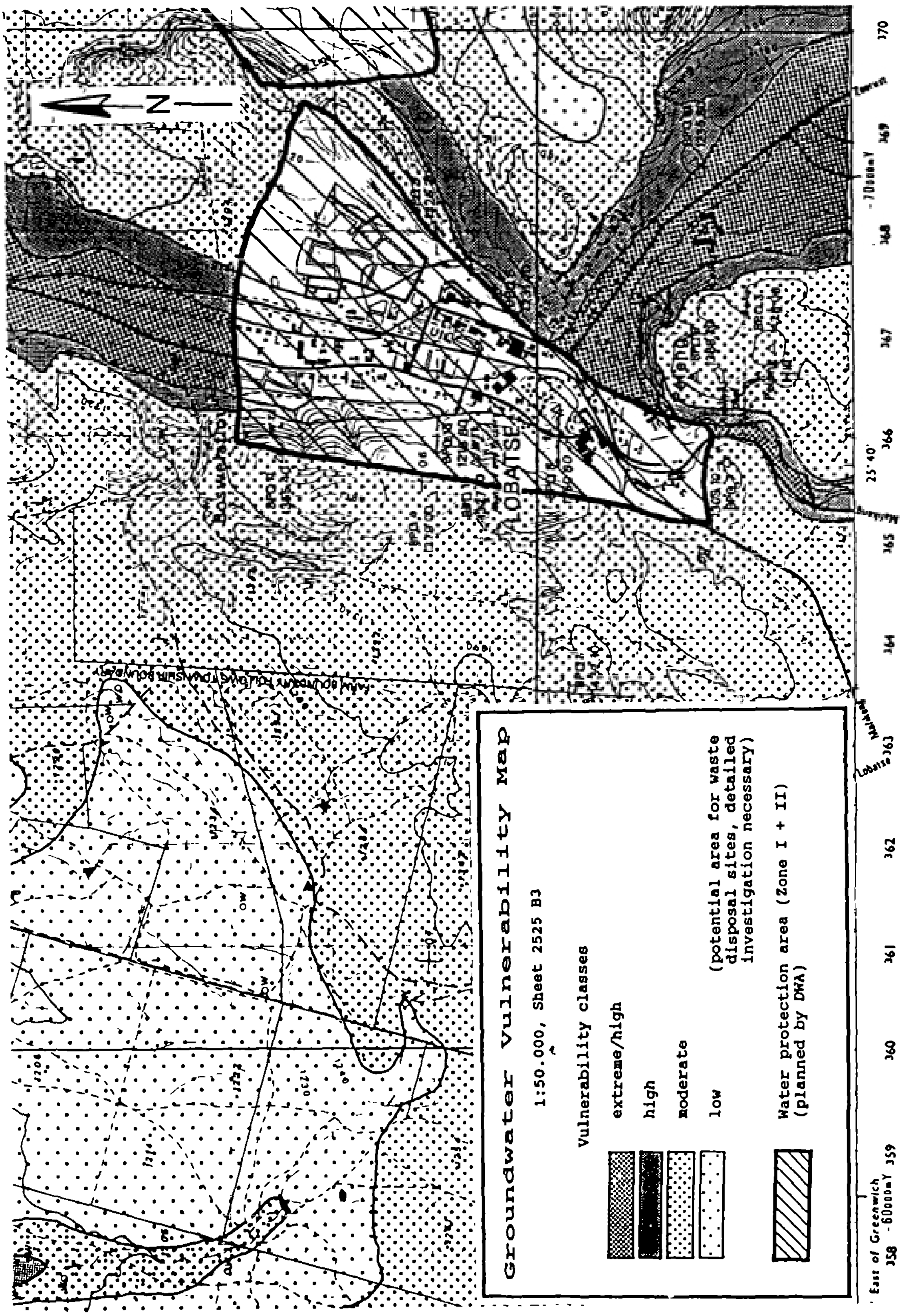


Fig. 2 Groundwater vulnerability map of Lobatse area.

effective than above the karstic dolomite area. High risk areas are also shown east of Lobatse along the Peleng river banks where groundwater level is near surface (5 to 20 m deep) and where the river recharges the groundwater.

Moderate vulnerability exists along the above mentioned range of hills where the groundwater level is deeper than 50 m. These areas are also characterized by a thin soil cover and by low groundwater resources.

Of particular interest to the project activities are the regions of low vulnerability, exhibiting a low risk to groundwater pollution. In these areas the groundwater level is deeper than 60 m, the groundwater resources are small and there is a certain cover of soil (mostly loamy sand, about 1 m thick), which acts to retard any potentially infiltrating rain water. The regions of low vulnerability are regarded as potential areas for the identification of possible waste disposal sites. But this selection is an initial step which has to be followed by more detailed geoscientific investigations. However, vulnerability mapping is not the only aspect for the identification of suitable landfill sites. There are other factors like land ownership, land use, accessibility, other environmental aspects, and most important, availability of funds for planning and implementation measures.

CONCLUSIONS

The first results of the Protection of Water Resources Project in the area around Lobatse show that the German model of vulnerability mapping is applicable to Botswana conditions. The maps are a contribution towards a controlled waste disposal programme by indicating areas suitable for safe disposal. In addition they will serve as guidelines in land management processes such as, land allocation, landuse planning, water supply schemes, and in selecting safer sites for waste disposal.

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THE CONTRIBUTION OF ECONOMIC INSTRUMENTS TOWARDS A SUSTAINABLE WATER SUPPLY IN BOTSWANA

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ABSTRACT

The paper explores -within the context of sustainable development- the major water concerns, and how they can be solved. It pays particular attention to the potential and actual role of economic instruments. Because of the widespread poverty, special attention must be paid to the impacts of such instruments on the income distribution.

Water consumption partly occurs in a market context, partly in a non-market context (producer = consumer). Due to rapidly increasing water demand and the fact that the "easy" solutions to increase water supply have largely run out, Botswana is concerned that water shortages may hamper people's basic needs and industrial development in future. Other sustainability concerns relate to the environment (pollution), social factors (equity and affordability) and economic grounds (cost recovery and efficiency). Prices, costs and the value of water may be instrumental in achieving a compromise between these goals.

Trends in pricing and their relationship with costs and the resource value are presented and the impact of prices and subsidies on water demand and supply are reviewed in order to assess their contribution towards an sustainable equilibrium between demand and supply. There is substantial scope to improve the performance of economic instruments such as prices, subsidies and tax relief. The long run marginal costs calculated in the Water Master Plan contributes to prices approaching the costs of water production, but it excludes many environmental considerations. Resource scarcity is partly reflected, where scarcity increases the water supply costs; the indirect users' value, non-use values and external impacts are not incorporated in water charges. Higher prices would increase the economic feasibility of water recycling and water harvesting and would generate investment capital needed for the expansion of the water supply systems. Government subsidies may discourage efficient resource use.

Discussion issues include: the need for groundwater monitoring to assess the "mining' element; greater emphasis on re-use of water and control of the water demand (curb non-essential demand, harmonise fees between urban and rural areas as far as non-essential use is concerned; provide more incentives for large scale users to increase water use efficiency); product diversification away from potable water only); more detailed analysis of the impact of price differentials on the location choice of enterprises; supply strategy emphasis of water saving because of long term considerations; the need for better regulation of the water consumption outside the market; and the introduction of unit water charges together with the issue of opportunity costs.

INTRODUCTION

In semi-arid countries, water is vital to people and their activities. This is obvious for those people, who have to make great financial sacrifice or physical effort to acquire water. Once water supplies are secured and subsidised however, people tend to take water almost for granted. Only when there is an acute shortage, is the true value of water rediscovered.

This paper makes some observations regarding the contribution of water costing and pricing towards securing a sustainable water supply. The following economic concepts will be used. The resource *value* comprises the direct users value + the indirect users' value (e.g. water supporting ecosystems and future users' value) + non-use values (Perrings et al., 1987; Pearce et al. 1989; see also figure 3). The resource *costs* are the financial and in-kind efforts associated with water consumption or production. The consumption *price* is the price paid by the consumer. In Botswana, the value of water is generally higher than the cost and price. In turn, the consumer costs are usually higher than the price. Before we elaborate further on the economic aspects, we have to understand the nature of the water resources, the physical and socioeconomic conditions of use and supply, and the major resource concerns.

THE NATURE OF BOTSWANA'S WATER RESOURCES

In as far as water is used for essential purposes, water is a basic need and should be financially and physically accessible to everybody. During the 1980s, there has been a rapid increase in the proportion of people with access to piped water: 77% in 1991 compared with 56% in 1981 (MFDP, 1993). But now the most difficult target group is left: the population scattered in lands and remote areas. The provision of water for this category of people requires more creativity and is costly on a per capita base.

Botswana currently makes use of ground- and surface water, roughly in the proportion of 2:1 (BNWMP, 1992). Groundwater is only partly renewable. The average recharge is 3 mm. per annum, but there are large inter-annual and spatial fluctuations. There is virtually no recharge in the western parts. Against this background, groundwater mining is common, especially during droughts and around mines. Surface water is in principle renewable if rains do not fail and the storage capacity is being maintained.

THE PHYSICAL AND SOCIOECONOMIC CONTEXT OF WATER USE AND SUPPLY

Resource use must be understood and evaluated in the broader physical and socioeconomic conditions. Physical features include:

- flat terrain with few suitable dam sites, mainly in the North
- high evaporation, particularly affecting the common shallow dams. This poses short-term difficulties to water supply managers, who -once the water works have been built- must recover their costs and weigh the promotion of water consumption against revenue losses due to evaporation.
- high temporal variability of rainfall, necessitating large storage dams to cater for droughts
- high spatial variability of rainfall, increasing the chances of the simultaneous occurrence of water shortages and surpluses in different parts of the country
- limited large-scale groundwater potential.

The major socioeconomic features include:

- rapid population growth of 3.5% (1981-1991) and a rapid concentration of the population in urban areas and in large villages
- rapid economic growth mainly driven by a rapid expansion of the mining sector; presently, economic growth is slowing down. This will adversely affect the hitherto healthy government finances, which allowed generous subsidies.
- a general increase in living conditions and welfare. The distribution of these benefits, however, is highly skew. Around 60% of the rural population and 30% of the urban population cannot meet their basic needs (CSO, 1989).
- an increasing spatial imbalance in population and development and water resources: most people and economic activities (except for mining and cattle rearing) are concentrated in Southeastern Botswana, whilst new water supplies are mostly in the North.

In view of the above characteristics, it is obvious that a sustainable water supply must be based on economic, social and ecological objectives. Figure 1 provides some useful suggestions as to what detailed goals could be pursued.

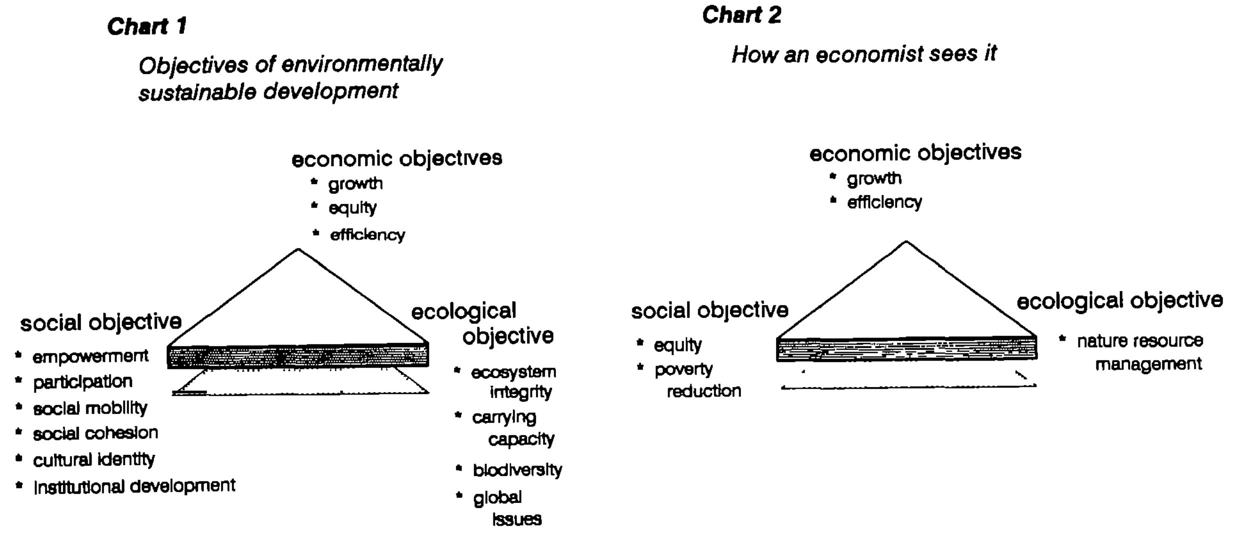

Figure 1: Multidisciplinary objectives related to sustainable resource use. (Source: Serageldin, 1993)

Clearly, a compromise must be struck between the goals of economic growth, efficiency, social justice (water for everybody) and sustainable water management.

RESOURCE CONCERNS

There are four major concerns related to water resources. First, the water supply may not be able to meet the rapidly growing demand. This general concern has led to the National Water Master Plan. The plan concluded that in future industrial and domestic water shortages are likely in South-eastern Botswana unless action is taken. Second, the ratio of ground-surface water consumption is unlikely to be sustainable in future. Most large-scale aquifers are already in use, and their future yields may decline. Thirdly, the water pollution is increasing and threatening potable water source. Nitrate pollution of groundwater, saline groundwater and organic pollution of surface water are common. The water quality of some boreholes around large settlements is poor (Lagerstedt, 1992). Fourthly, the entire population and economy must be provided with a reliable water supply for essential purposes. Appropriate solutions need to be found for the remote areas with a scattered population.

In response to these concerns, the government has embarked on an large-scale investment programme to increase the capacity of ground- and surface water sources and to link both through a network in Eastern Botswana (the North-South carrier). Much less attention is being paid to other alleviating measures such as increasing user efficiency, water harvesting and water recycling. The following coping strategies may be distinguished for resource scarcity:

i. increasing the resource supply (e.g. increased water harvesting, new aquifers). This is not always possible, and begs the question whether the supply increase can be sustained in future
ii. increasing the resource use efficiency: this may take various forms such as recycling and suppressing non-essential consumption (e.g. gardening, car washing etc.).
ii. diversification towards activities which use less water. For example, industrial activities with a low water consumption should be encouraged. Similarly, irrigation should be discouraged because of its high water consumption.
iv. movement of resource demand to surplus areas. For example, water-intensive activities may be moved to areas with adequate water supply.

THE MARKET STRUCTURE

In this section, we examine the role of the price mechanism in bringing about proper adjustments. If adjustments are not forthcoming or prove inadequate, physical water shortages may result, forcibly suppressing the consumption. In Botswana, this has happened in rural villages, with inadequate capacity to meet the rapid demand growth. It also occurs during droughts, when the supply of surface water decreases. For policy purposes, the different adjustment options must be simultaneously pursued to spread the risks. Such a response also increases the chances of meeting future essential water needs in a cost-effective manner.

There is no distinct market in the traditional economic sense. Water use can be subdivided into two main categories:

- non-market consumption: the producer and consumer are the same, and no formal price is established. Examples: livestock, wildlife and some mines. At present, such water consumption may account for at least half the annual consumption.

- "market" consumption, but the "market" is in fact segmented along *sectoral* and *spatial* lines.

The ownership conditions of water is not clear. Presumably, government "owns" the resource on behalf of its citizens. An important part of the water consumption is not formally marketed, but directly used by the producers (livestock, wildlife, some mines and domestic use in lands areas). There is no formal price, and government influence is restricted to regulations of the Land Boards and the Water Apportionment Board. It appears that the water is "owned" by the users: the actual amount of water consumed is not charged, but all water costs have to be met by the producers/consumers. The water costs are regressive and may therefore form a disincentive for efficient water use (Table 1). The introduction of water charges may increase water use efficiency, unless the threat of water shortages is already felt.

Table 1: Resource pricing and principles

Use	Water sources	Institution	Pricing Principle	Price Details
urban use	ground and surface water	WUC	full cost recovery	progressive rates with increasing use; rates lower in the north
major rural villages	mostly ground water	DWA	standpipes free; recovery of recurrent costs; charges for yard/ house connection	progressive rates, but less progressive than in urban areas
rural villages	groundwater	District Councils	standpipes free; charges for yard/ house connections	
livestock	30% surface; 70% groundwater	Land Boards	all investment + recurrent costs	regressive; no charges related to amount used
Mines	ground + surface	WUC + companies	full cost recovery (WUC)	WUC supply + own supply
Wildlife	mostly surface water	DWNP	full costs of boreholes	regressive

The "water market" is oligopolistic with a few suppliers dividing supply responsibilities such as the Department of Water Affairs DWA (major villages), the district councils (rural villages) and Water Utilities Corporation WUC (urban water supply and industrial water supply). The water supply through government and the WUC has annually fixed prices. It is not the result of market forces. Government failures may occur, when environmental factors are not adequately included into the price-setting.

As far as the market segment is concerned, resource scarcity would be expected to lead to higher prices, raising opportunities to exploit new, more expensive supply sources, providing incentives to restrict demand and to use alternative water sources (e.g.

rainwater harvesting). The role of prices in stimulating resource scarcity coping mechanisms in traditional economic theory is summarised in figure 2. It is technocratically assumed that new water sources can be identified. As stated earlier, water shortages are mainly a local phenomenon in Botswana.

The "water"-market may be typified as a sellers market because of the oligopoly and the rapidly growing water demand fuelled by population growth, welfare increases and an expanding economy. The supply has simultaneously increased, but at a slower rate and at increasing distance of the demand. Moreover, the supply fluctuates with climatic conditions (wet and drought periods).

Below the prices and subsidies are discussed, followed by an analysis of supply and demand

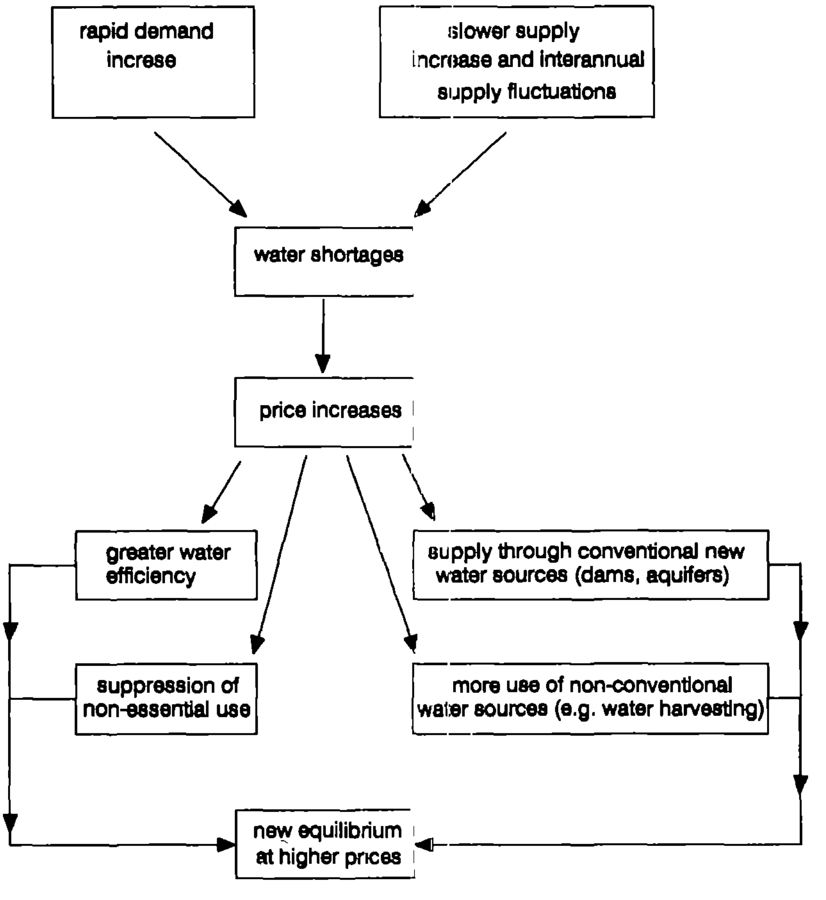

Figure 2: The Potential Contribution of the Market Mechanism to a Sustainable Water Supply

Water Prices, Costs and Subsidies

As a result of the different institutions responsible for water supply and the variety of economic, social and environmental factors taken into account, the principles of water charges vary substantially (Table 1). The "non"-market segment does not have a formal price; unit water consumption costs decrease with increasing consumption, potentially encouraging inefficient water use. In this case, the opportunity costs of such water use must be carefully examined: is it a proper use of a scarce natural resource? With respect to the "water market", the price system is mostly based on social and economic factors; environmental influences only play a limited role, and are restricted to implicit resource scarcity -as reflected by increasing supply costs- and environmental mitigation measures, identified through EIAs (Sefe, these proceedings). However, the pricing system does not differentiate between renewable and non-renewable water resources. The present pricing policy is determined by government and is based on equity, affordability and efficiency (NDP7). The system has the following characteristics (Tables 2 and 3):

i water charges are strongly progressive with increasing use. This forms an incentive to use water efficiently.

ii the lowest water charges -up to 10 m3 in urban areas- have remained constant in real terms during the 1980s. Rates for 11-15 m3 initially increased, but later substantially decreased.

iii water charges for the large users have almost tripled during the 1980s in real terms.

iv spatial price differences within urban areas reflect the differences in the costs of water supply. The dismissal of this incentive for relocation as ineffective, explains why the spatial differences have not increased after the mid 1980s. Further study is needed to identify conditions, under which the instrument is likely to work.

v water charges in rural areas for private connections are lower and less progressive than in urban areas. They declined in real terms during the 1980s, but they have been increased annually since 1990. There appears to be a major contradiction between the urban and rural rate structure. It is assumed that essential water use is charged at a low rate. However, where as essential use in urban areas is up to 10 m3, in rural areas it is double this level, despite the fact that essential use is unrelated whether urban or rural.

Table 2: Trend in water prices in Gaborone (constant prices 1990)

Use band	81/82	84/85	1985/86	1990	1993
0-10 m3	52	58	60	55	54
11-15 m3	78	141	184	55	160
16-25 m3	78	141	184	215	205
26-30 m3	78	141	184	215	281
31-40 m3	104	199	251	215	281
41-50 m3	104	199	251	292	281
50 + m3	91	259	340	292	281

Sources: Annual Reports WUC.

Present water charges in Southeastern Botswana are still well below the long run marginal costs (LRMC) of P4.75 (1991 prices). From an environmental perspective, the real water charges should be higher. The LRMC only reflect the design and construction costs of the new water supply systems, and remains below the total economic value of the resource (Table 4). To reflect the value, the price of water should not only include the direct users' costs, but also the indirect users' values and non-use values.

Table 3: Current Rural and Gaborone Water Charges (November 1993)

Use Band	GABORONE	RURAL AREAS
0- 5 M3	85	45
6-10 M3	85	90
11-15 m3	250	90
16-20 m3	320	90
21-25 m3	320	180
26-30 m3	440	180
31-40 m3	440	180
over 40 m3	440	400[a]

Sources: DWA and WUC. [a] for Mogoditshane and Tlokweng.

Unfortunately, the latter categories are more difficult to quantify ("intangibles"). Rising water supply costs partly reflect the increasing resource scarcity, but the price should include the external impacts of water extraction on the local ecosystem (function loss, biodiversity etc). With the exception of groundwater table changes and changes in surface water sources, ecosystem-function losses may not be so important as yet. However, they could become very important on the longer run, if the Okavango and/or Zambezi sources are tapped.

Water supply systems have been highly subsidised by government. Subsidies have posed a burden to government finances and have discouraged more efficient water use (Hagos, these proceedings). Given the rapidly increasing water supply costs and a levelling off of government revenues, it is inevitable that the percentage of government subsidies must be reduced. Government subsidies for major water supplies will decrease from 76% in 1990 to 40% in 2000 (BNWMP, 1992). In absolute terms, the subsidies are expected to decrease by 50% during the plan period. Future subsidies need better targeting towards essential usage by human being and for productive purposes. It may be worthwhile to change cross-subsidisation from government to the consumers into subsidies from non-essential use to essential use. For policy-making, it would also be interesting to compare total and per capita subsidies in urban areas, major villages, other villages and lands areas.

Table 4: The Total Economic Value of Water in Botswana

VALUE COMPONENTS	VALUE SUB-COMPONENTS	EXAMPLES
Use value	direct use	food, health, livestock, wildlife, industry, government households
	indirect use	ecosystems and indirectly human beings
Non-use values	Option value	future direct and indirect use such as biodiversity, conservation of habitat etc.
	Existence value, based on e.g. moral grounds	conservation of habitats and species

Source: based on Serageldin, 1993.

Water Supply

Because of the climatic conditions, total water supply varies annually. Surface water reserves fluctuate with rainfall; so does the recharge of groundwater. The public water supply has traditionally aimed at meeting existing essential and non-essential demands. In some cases, there have been supply constraints which have suppressed consumption (lower than demand). Shortages have occurred in villages and in urban areas generally during droughts. The main problem is a spatial mismatch of new demand and supply, causing very high water supply costs in Southeastern Botswana. The North-South carrier aims to prevent future shortages in Southeastern Botswana.

The main potential sources of supply include:

i. groundwater

ii. surface water: dams and water harvesting

iii. reuse of water and purification of effluent.

iv. purchases from neighbouring countries. Opportunities are presently limited because most countries in the region face water shortages. However, it can be useful and cost-effective in border regions.

v. reduction of water supply losses (up to 40% in rural villages;

The WUC produces potable and raw water (the latter is much cheaper), but the volume of raw water sold has decreased in recent years.

The supply curve does not differentiate between household and productive enterprises; instead it differs based on location. In figure 3, the supply curves for Gaborone, Francistown and private connections in rural areas are shown. Because of its band structure, tariffs contributes more to efficient resource use among households than among enterprises (most enterprises will be in the highest tariff band).

Another supply problem relates to the lands areas and remote areas. Because of the low population density, the costs of a water supply system would be very high. The same applies to the provision of water through bowsers (up to P50/m3; Gould, 1991). It appears that for this category of users local ground and surface water sources need to be better exploited. This includes water harvesting techniques and groundwater utilisation with low external maintenance requirements.

The Demand for Water

The demand for water is rapidly increasing, and the structure of water use is changing. During the 1980s, water consumption in Botswana was correlated to both population growth and economic growth, despite the water restriction during the drought.

The demand can be categorised in two ways. The first distinction is between essential and non-essential use. For example, human consumption is essential use, but watering gardens is non-essential. The price elasticity of essential usage is usually low. The price elasticity of non-essential use is higher because there are alternatives (less watering of the gardens). Regrettably, there are no reliable elasticity estimates available for Botswana. In other words, we do not know the slope of the demand curve for water (Figure 3). Households are likely to have a curve similar to D1, where it is crucial for policy purpose to determine the slope of the curve and point I. However, the demand curve for a household, which does not pay its own water bill would probably be shaped more like D2. The water consumption curve of productive activities is determined by the production structure and may greatly vary between enterprises. In most cases, the demand curve will intersect the supply curve in the highest price band.

The second distinction is between scattered and concentrated use. Water use by cattle, wildlife and population at the lands is scattered all over the country. Villages, mines and urban areas have a strong "point" demand. Scattered use is still substantial (36% in 1990), but its share of total consumption is predicted to decline to 27% and 16% in the years 2000 and 2020 respectively (BNWMP, 1992).

The increase in water use results from population growth, economic growth, and increased per capita use because of improved welfare levels. The National Water Master Plan estimated an income elasticity of water consumption of 0.46. In other words, an 1% income increase in real terms would lead to a 0.46% increase in the water consumption.

This reflects better living conditions. For example, in major villages, per capita water consumption ranges from 7-26 l/day for standpipes to 85-201 l/day for house connection. Similarly in urban areas, water consumption in SHHA-areas is 28-65 l/day compared with 346-382 in high cost areas (BNWMP, 1992).

In order to optimise the contribution of prices on sustainable water supply, it is important to know the exact nature of the demand curves, the intersections with the supply curves. The figure can also be used to illustrate the impact of price subsidies, i.e. lower water prices.

Figure 3 raises a number of discussion topics:

i if the steep increase in water rates occurs in the essential demand part (with low price elasticity), it will have mainly a revenue raising function, but makes little difference on water consumption.

ii in case where employers pay water bills of their employees, water charges will only generate extra revenues, but have a limited impact on water consumption. Thus, this reduces the effectiveness of price incentives.

iii households in Gaborone have a greater financial incentive to curb non-essential use than households elsewhere.

iv because of the high marginal rates, income increase in Gaborone will lead to a smaller demand increase than in rural areas and in Francistown.

v large commercial water consumers face high marginal rates and high water bills, but they have no other incentives to reduce water consumption. The strength of this incentive probably depends on the market conditions. If the market is highly competitive, it may be impossible to simply pass on high water costs to the consumers; in this event, a high water price will offer incentive for water conservation. Offering additional incentives such as subsidies or tax relief for the adoption of water conservation techniques, recycling, rainwater collection etc. should be giving serious consideration. These subsidies can be justified because of their large social benefits.

TOWARDS A SUSTAINABLE WATER SUPPLY: SOME POINTS FOR DISCUSSION

A secure long term water supply is the country's water life-line for the future. Present plans strike a compromise between social and economic criteria, and to a lesser extent environmental criteria. There is a clear plan of action:

i. increase the conventional water supplies such as aquifers and dams (including some water imports from South Africa)

ii. increase water charges to raise government funds and to stimulate greater users' efficiency

iii. linkage of the major sources of water supply in order to balance regional shortages and surpluses ("systems'-benefits).

iv. increase water prices, but keep water consumption from standpipes free for social reasons.

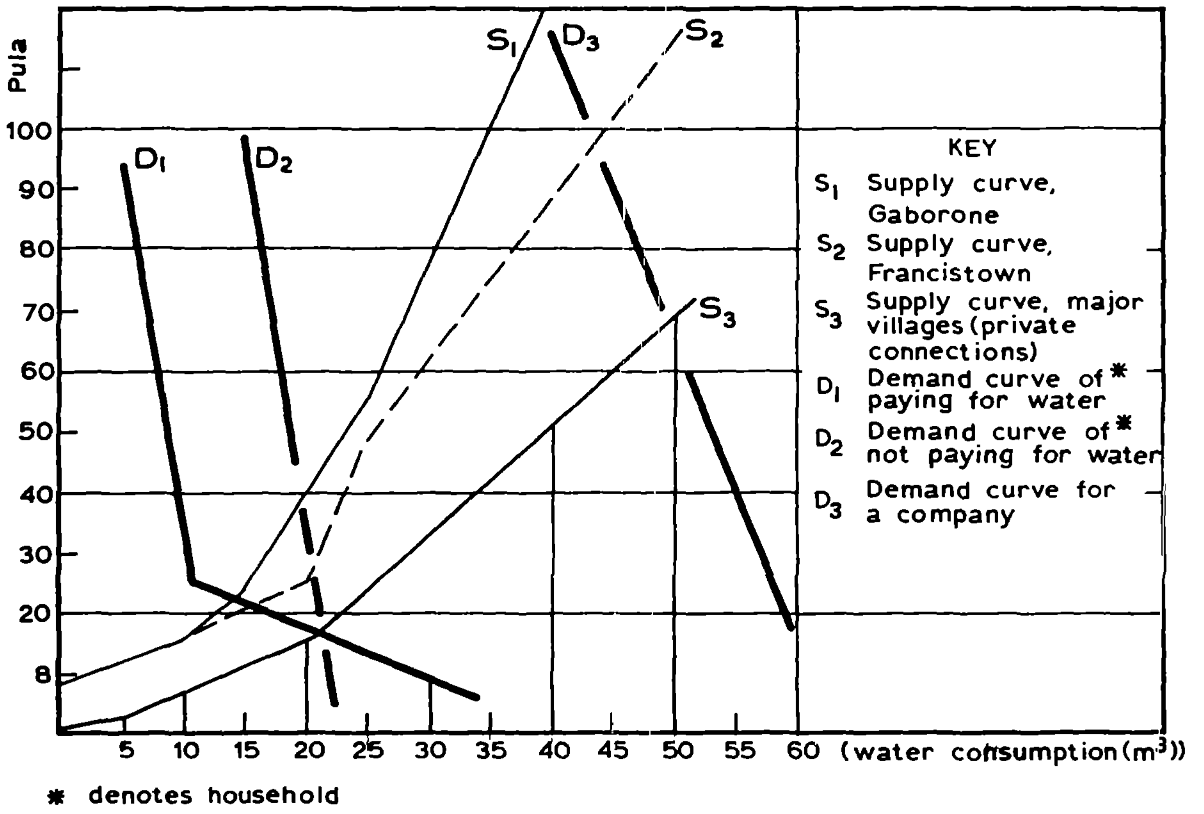

Figure 3: Spatial Supply Curves and Possible Curves for Water Consumption by Households and Companies

The plan does not, however, answer more strategic issues, crucial to a sustainable water supply.

First, data are lacking regarding to what extent ground water mining occurs. Obviously, this is important for future water supplies, and more intensive monitoring of groundwater sources is urgently needed. From the perspective of sustainable development, the following guidelines may be adopted for water resource management. Where the water resource is renewable, consumption evidently must not exceed its regeneration. Some storage is possible but only for relatively short periods because of the high evaporation. Where the resource is not renewable, the resource must be mined in such a way that upon its depletion alternative water sources and water-saving technologies are in place.

A price increase could be beneficial. This situation applies to the diamond mines of Jwaneng and Orapa.

Second, the plan pays little attention to the reuse of water and small-scale water harvesting. It is to be expected that these options gain viability with rising water charges. The high initial costs in combination with the large social benefits, would justify limited subsidies.

Third, there is no strategy to control demand, in particular to reduce non-essential consumption. In order to use economic instruments in such a strategy, it is imperative to gain more information about the price and income elasticities of households and enterprises. Non-essential demand should not be subsidised and therefore, rates should be similarly progressive in urban and rural areas. Consequently, rural charges above 10 m3 should be substantially increased. This has the added advantage that income increases will lead to a smaller increase in water demand. In order to control demand, it is necessary to prioritise water consumption. Demand can be prioritised in the following order: people's essential needs, productive purposes with large economic spin-offs and consumptive, non-essential, use. Obviously, this would require a clear political choice as to what essential use is. Related to the water demand, consideration must be given to the supply of different qualities of water. Some industrial and agricultural consumption could manage with lower quality water than that provided at present (although it leads to extra -one time- infrastructural costs).

Fourth, spatial price differences are considered to have a little impact on the location of industries. The evidence is, however, minimal. Private sector response is likely to vary depending on the relative importance of water in terms of the total production costs and on other possible disadvantages of relocation. This subject requires further study. Water planning pays little attention to the threat and potential costs of pollution.

Fifth, present policy almost exclusively focuses on catchment area protection and ad-hoc measures. However, systematic measures need to be considered to implement the polluter-pays-principle, as stated in the National Conservation Strategy.

Sixth, from a long term water perspective suppliers must always be encouraged to increase water use efficiency and to reduce water consumption. This may, on the short term, cause revenue losses because of higher evaporation losses. Those losses, however, must be incorporated in the short term water price. Such a strategy is most suitable to keep the inevitable long term prices to a minimum.

Seventh, from a strategic point of view, government needs to increase its control over non-market water use (livestock, mines, lands areas). There are insufficient incentives to encourage efficient water use, and the opportunity costs of water need to be considered (is this good water use given present and future needs?). The feasibility of the introduction of water charges in these sectors should be considered.

This brings us to the role of water charges and subsidies in promoting a sustainable water supply. Higher prices may have three positive impacts: they generate funds for the required investments; they may -depending on the price elasticity of demand- stimulate efficient water use; finally, they render non-conventional water supply and conservation techniques more feasible. Subsidies have a mixed impact: they are necessary to guarantee adequate access to the entire population, but at the same time, they may lead to wasteful resource use. Therefore, subsidies must be better targeted to the "real poor" and to household and enterprise water saving devices, where the initial private investments are high but the social -and not the private- benefits are substantial (e.g. rainwater tanks). Moreover, non-essential water consumption could be charged extra to subsidise essential use (in stead of reliance on government subsidies).

Contrary to common beliefs, water prices have not dramatically increased during the 1980s (Table 2). Large price increase still lie ahead to achieve the Master Plan targets. This requires political courage and decisiveness. Water prices should in principle reflect the total economic value or TEV. At present, prices are below the production costs and well below the TEV. The existing government plans will bring the prices closer to the real supply costs, but there are no plans to bring them in line with the TEV. Higher prices contribute to the restoration of the resource balance, but they need to be supplemented by regulatory measures such as the protection of water catchment areas and clarity about the ownership of water resources. Moreover, the present charge differentials mostly influence household consumption. There is no price differential for enterprises, and it would be worthwhile to explore opportunities, other than the generally high rate, to further stimulate water consumption efficiency.

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THE ROLE OF ENVIRONMENTAL IMPACT ASSESSMENT IN WATER RESOURCES PROJECTS AS A TOOL FOR JOINT MANAGEMENT OF BOTH THE ENVIRONMENT AND WATER IN BOTSWANA

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ABSTRACT

Every water resource project represents an intervention in the hydrologic cycle on the part of man. As water is an integral constituent of the environment, such interventions impact on the intricate relationships that exist among the various elements of the environment. There is a need therefore to harmonise water resource projects with the environment. That can only be achieved by adopting an integrated approach to the planning and management of water resources.

It is argued herein that the EIA process can be utilised in integrated planning and management of water resources within the global context of the environment, particularly if the monitoring stage of the EIA process is vigorously undertaken. The paper reviews the current practice of the EIA process in Botswana using the Kolobeng-Metsemotlhaba Dams EIA as a reference point and proposes an EIA procedure by which this integrated planning and management can be achieved.

INTRODUCTION

Every water resource project, whether it is concerned with surface or sub-surface water represents an intervention on the part of man into the hydrological cycle. This cycle is an open system with well-defined pathways along which water is transferred in one of its three phases, namely, solid, liquid and gas. Along the pathways, the water is temporarily held in 'stores' such as the atmosphere, aquifers, soils, rivers, lakes and, even, in plant tissue. As the hydrologic cycle is a system, these stores are, in fact, elements of this system. (Some of the elements are systems in their own right).

Intricate relationships exist between the various elements of this system which ensure its smooth operation. Since the advent of man, this intricate relationship has come under constant interference. In most cases, these interventions lead to irreparable changes in the system. With demand for water bound to increase in the future, the adverse impact on the system is bound to grow unless something is done to change current planning and management processes.

It is argued herein that the EIA process can be utilised in integrated planning and management of water resources within global context of the environment. The paper proposes an EIA procedure by which this integrated planning and management can be achieved.

MAIN ELEMENTS OF THE EIA PROCESS

Since the inception of EIA in the early 1970's it has come to be regarded as an important tool for environmental management (Wathern, 1988). As the complexities the man-environment interaction grew, EIA methodology also grew more and more complex. It is a handy technique for deciding in an objective manner between often competing alternatives for the use of environmental resources, including water. In this regard, EIA methodology is a process for analysing and synthesising the often large volume of data needed for rational decision making. A good EIA report should contain the following:

i) a collation of the appropriate information necessary for the particular decision to be taken
ii) an indication of expected changes in environmental parameters after implementation of the project
iii) a routine for monitoring after the implementation so as to record and analyse the actual changes that have occurred.

Six key components of environmental impact studies for water resources projects may be recognised as discussed below.

Baseline studies:
The term, Baseline studies, refers to a study of conditions existing at a point in time against which subsequent changes can be detected through monitoring (Hirsch, 1980). They provide information on the issues identified during the scoping exercise.

Impact identification
This component of the EIA process is normally the first stage. The probable impacts of relevance to the particular project are identified and even ranked in order of probable severity. This stage, if done properly leads to a reduction in effort later on, as only the relevant impacts will be selected for closer attention.

There is probably no limit to the kind of impact a water resource project may have on the environment. Some impacts mentioned in the literature are listed in Table 1. This list clearly illustrates the wide range of possible impacts.

Prediction of impacts on various environmental factors
This phase usually involves the use of mathematical models to 'predict' the likely impact of the proposed project on the environment. The environment is represented by a set of key variables which are selected normally because they are readily quantifiable. It should be noted, however, that sometimes what is readily quantifiable may not hold much relevance to explaining the impact on the environment (French and Krenkel, 1981).

Associated with the stage of impact prediction in the EIA process is monitoring. Monitoring is a key aspect of EIA because prediction implies a degree of uncertainty. This degree of uncertainty is not easy to evaluate at the pre-project stage because the 'true' impact is not known. Thus techniques to monitor what is being predicted need to be considered at this stage. Unfortunately, the tendency is there to accept prediction as the end product and ignore the monitoring aspect once the project is in place.

Table 1: **Some impacts identified for various water resource projects**

i) protection against high floods and droughts
ii) siltation of lakes
iii) loss of silt to agriculture
iv) loss of fisheries potential
v) changes in water quality
vi) destruction of arable land due to poor management of irrigation projects.
vii) impact of public health-especially spread of schistosomiasis, liver fluke and malaria into new areas.
viii) social dislocation as a result of resettling large populations.
ix soil salinization
x) eutrophication
xi) bacterial growth
xii) deoxygenation
xiii) perturbation of downstream hydrology and aquatic systems.
xiv) effects on archaeological remains
xv) impact on ground-water geology
xvi) impact on fish nutrition and production
xviii) impact on lake assimilative capacity for waste-waters
xix) increased evaporation
xx) reservoir-induced earthquakes.
xxi) ground subsidence as a result of over pumping of aquifers
xxii) intrusion of saline water into aquifers

Trade-off analyses

This is the stage where, in the traditional EIA process, cost-benefit or trade-off analyses (not necessarily in money terms) are undertaken to aid decision making. Recourse is usually made to quantitative techniques but it is worth noting that not all impacts can be quantified. It is also the stage for resolving resource use conflicts and competition.

Identification and evaluation of mitigation measures

At this stage of the EIA process, measures to mitigate the identified impacts are recommended. This activity is undertaken with the overriding aim of increasing the positive side of the EIA process.

THE ROLE OF EIA

The primary role of the EIA process is to harmonise a proposed water resource project with the environment. However, this does not imply that the role of EIA is to compel decision makers to adopt the least environmentally damaging alternative. There maybe more compelling social and economic arguments not to adopt a least environmentally damaging alternative.

Most often, water projects arouse considerable passion not only because water is a key constituent of the physical environment but also because of the high opportunity costs that such projects entail. These high opportunity costs may be intangible as, for example, an aesthetically appealing environment or tangible as, for example, loss of grazing land due to impoundment. It should be the role of the EIA process to provide the decision maker with the means to objectively adjudicate between competing demands.

There is yet another role that EIA can perform. All over the world, but more so the third world, the period of observation of natural processes is rather short. In this country for example, rainfall data collection started only about 70 years ago while observations on boreholes started even much later. In addition, however, these limited observations are available only at scattered points. The rain gauge network in Botswana is still sparse. Yet the necessity of providing water has meant the design and construction of hydraulic structures intended to last many times the length of data on which their design was based. Under these circumstances the uncertainty associated with impact prediction is increased immeasurably.

There is yet another role that the EIA process can play as a tool for integrated management of water and the environment. It is possible to use the EIA process as a means of filling in the gap in knowledge about the impact of water resource projects on the environment. To be able to do this requires the execution of all the stages of the EIA process. Figure 1 shows a simplified version of the EIA process. It so happens, unfortunately, that the last stage after the project is often forgotten. Yet for the purposes of knowledge building, this should be the most important stage in the whole EIA process.

FIGURE 1: A SIMPLIFIED MODEL OF THE EIA PROCESS

BASELINE STUDIES ⇒ IMPACT PREDICTION ⇒ PROJECT ⇒ MONITORING PROGRAMME

THE EIA PROCESS IN BOTSWANA WITH REGARD TO WATER RESOURCES PROJECTS

Botswana was one of the first three African countries to have an early experience of EIA (Klennert, 1984). It is now a fairly standard procedure for all 'major' water resource projects. For a definitive description of the EIA process in Botswana, as far as water projects are concerned, one must turn to the EIA of the Kolobeng and Metsemotlhaba Dams (MLGL, 1986; MacDonald and Partners, 1988). Space limitations preclude an exhaustive discussion of the report. The EIA for the Kolobeng and Metsemotlhaba Dams, which eventually led to the Bokaa Dam Project, is definitive in many respects:

1. The six stages of the EIA process previously discussed can be discerned from the report.
2. The execution of the project also indicates that the EIA was taken into consideration when it was finally decided to build the dam at Bokaa. Thus the report facilitated an objective assessment of the various options.
3. The report was at pains to recommend monitoring, although it limited monitoring to compensation issues only.
4. It is, perhaps, the first time when EIA was not used merely as a tool for project appraisal, but for more involved environmental analysis.
5. When it was decided to locate the dam at Bokaa, a more detailed EIA for the chosen location was undertaken.
6. The EIA also dealt with the impact of the construction activity itself.

Adequate as these features maybe, there is a feeling that there are some items that are missing or are not emphasized strongly enough in this EIA.

STRENGTHENING THE EIA PROCESS IN BOTSWANA

A study of the Kolobeng-Metsemotlhaba Dams EIA Reports in the light of EIA theory and its practice in other countries, reveals that the process as it is practised in Botswana can be strengthened in many respects.

Figure 2 is a flow diagram of a proposed EIA process. The main features of the proposed system are as follows:

1. The importance of the 'project definition' stage cannot be over-emphasised. It is essential to include community liaison and discussion in this stage. Furthermore the eventual project(s) must be predicated upon a thorough needs assessment. This stage, if done properly, may save much toil later on. At the moment, this stage appears to be done exclusively by the 'experts'.

2. The need to identify possible options. Single option EIA tends to reduce the EIA process to one of project appraisal for which better suited techniques exist. Identifying options and possible combinations of them will facilitate an integrated approach to water resource planning.

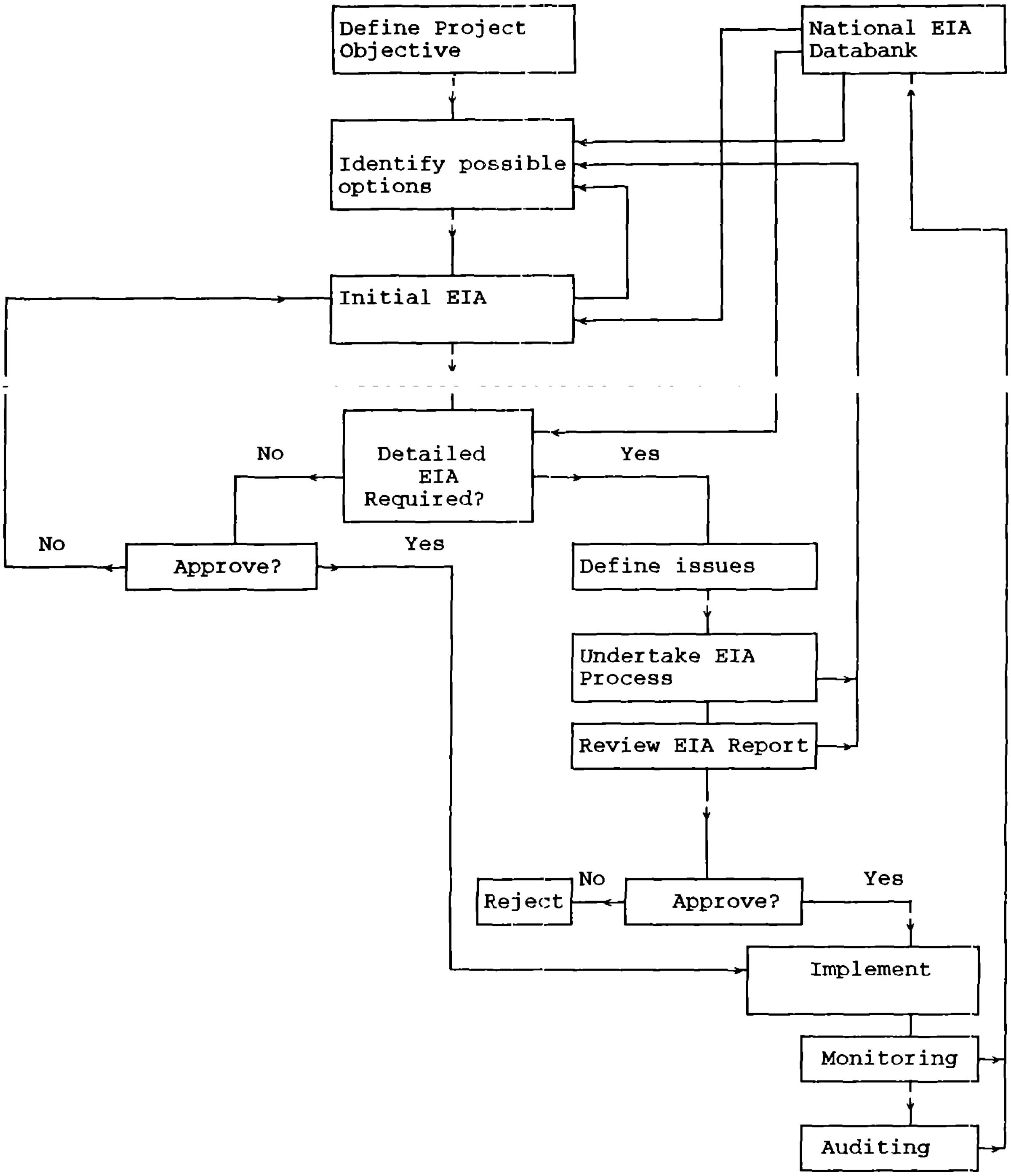
3. Figure 2 is in two parts. In the top half, can be seen 'Initial EIA'. This part is essential for the narrowing down of the possible options. It should be a quick-checking kind of assessment that could contribute immensely to preliminary decision-making. This was, in fact, done in the case of the Kolobeng-Metsemotlhaba Dams EIA.

4. The proposed model has several decision boxes. In order to be able to proceed from these boxes in a rational manner, it is necessary to establish threshold values for selected environmental indicators. For example, if a detailed E.I.A. is not required the decision to 'approve' a project should not be automatic. The decision must be based on a set of criteria suitable for the environment of Botswana. It should, however, be recognised that establishing a kind of national environmental impact yardstick is not a thing that can be done in a hurry. But it is necessary to set such a goal now. It also requires periodic reviews of the EIA process particularly with a view to identifying sensitive environmental indicators and their level of sensitivity.

A related issue at his point, is the need to establish a set of criteria by which projects are selected for EIA study. At present, only 'large' projects, especially where external funding sources are involved, that are subjected to E.I.A. study. Apart from the question of determining how 'large' is large, it is necessary to emphasize that water resource projects like farm dams (or drought relief dams) can and do have negative impacts on the environment. This is illustrated by the recent study on small dams in Botswana(Gibb and Partners, 1992). The World Bank recently published an Operational Directive on E.A. [E.I.A.](World Bank, 1991). But this is strictly speaking a general guideline and cannot replace country-specific guidelines.

5. The proposed model in Figure 2 shows a link between the stage where the EIA processes are conducted and the stage where available options are identified. This link is necessary because it may reveal other possible alternatives that may have been overlooked. The IUCN report (IUCN, 1992) on the Southern Okavango Integrated Water Project (SMEC, 1991) revealed options that were overlooked.

FIGURE 2: FLOW DIAGRAM OF A POSSIBLE EIA SYSTEM



6. The stages of monitoring and auditing, which traditionally have been the weak links in the EIA process in Botswana, also need to be strengthened. As the Kolobeng-Metsemotlhaba Dams EIA report shows, it seems the fundamental reason for the current weakness lies in the fact that monitoring is always linked to compensation issues. The report observed that:"The situation poses a dilemma: present information is insufficient to predict the

consequences for downstream farmers of dam construction, and quite inadequate to form a basis for compensation..."

But the issue of monitoring and compensation need not pose any dilemma if the two are de-coupled. What is needed for compensation purposes is an assemblage of predicted impacts. A mathematical model of the system, informed by experience gained from past projects, can be used for this purpose (Canter, 1985). Monitoring the impact of a water resource project on the environment must, of necessity, be a long-term undertaking. It is only by this kind of long-term monitoring that some hard facts can be learnt for transfer to other projects.

There is also an institutional aspect to the apparent neglect of monitoring and auditing stages of the EIA process in Botswana. At present, studies pertaining to water resource projects are carried out under the auspices of the Department of Water Affairs (DWA). Once construction is completed and the project handed over to the Water Utilities Corporation (WUC), the responsibility of DWA appears to come to an end. There is a need for instituting a mechanism whereby DWA can continue to secure budgetary resources for monitoring and auditing purposes for as long as possible.

7.One additional way in which EIA practice in Botswana can be strengthened is the establishment of a National Environmental Impact Databank. Such a databank will collate the results of the monitoring and auditing exercises from the various projects nationwide. The databank will be an invaluable asset at the initial and detailed EIA stages in Figure 2. These are the stages where the collective knowledge and experience gained from an earlier project can be applied to a current one. The databank can also be useful in determining compensation issues for future water resource projects. It is through such a databank that the role of EIA in integrated management of the environment can be achieved.

CONCLUSION

It can be concluded from the foregoing discussion that the EIA process can be a tool for achieving the goal of integrated environmental management. However, in order to achieve this goal, Botswana's experience of the EIA process needs to be strengthened in several respects:

i) the need to move from single to multiple-option planning of water projects;
ii) the need to establish a national EIA yardstick as a minimum requirement;
iii) need to review the institutional arrangements under which water projects are carried out; there is a need for an institutional structure with a clear set of guidelines / methodologies suitable to the particular environmental circumstance of Botswana.
iv) the need to strengthen the monitoring and auditing stages of the EIA process;
v) the need to establish a National Environmental Impact Databank.

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CONJUNCTIVE USE OF SURFACE AND GROUND WATER IN BOTSWANA - URBAN AND RURAL ASPECTS

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ABSTRACT

The combined use of ground and surface water in semi-arid regions such as Botswana is a key element in any integrated approach to management of water resources. However, there are many aspects of conjunctive use which make efficient implementation difficult. Some of these difficulties are discussed in this paper.

First, there are huge differences of scale between rural and urban settings. Conjunctive use problems can be addressed at the level of a low yield and low quality village borehole combined with roof top catchments, or, conversely, at the level and complexity of the North-South Carrier where millions of cubic metres water per year need to be processed through pipelines in eastern Botswana combining resources of large dams and wellfields.

Second, the integration of the different disciplines involved in respectively the management of surface and underground water resources leaves much to be desired. For example, typical hydrogeological problems such as ground water monitoring, (artificial) recharge, mining, regional flow modelling, salinity and pollution are not well understood by the engineers that are designing and operating pipelines and transfer schemes. Hydrogeologists, on the other hand, feel uncomfortable when confronted with storage design, operating procedures or economic aspects, whether these are at the scale of roof top catchments or large dams. Increasing institutional integration is required to cope with applied research and management aspects.

INTRODUCTION

Optimum water development can only be attained by conjunctive utilization of surface and ground water reservoirs. Conjunctive use of water resources in the management of water resources may simply mean use of ground water when the dams have dried up because of drought. The Botswana National Water Master Plan (BNWMP, vols 1-12, 1991) uses the term "conjunctive use" in this sense. For example in the water modelling exercise of eastern Botswana the surface water resources may have to be augmented by the ground water from the Palla Road and Mmamabula Wellfields when the dams fail (BNWMP, 1992).

However, in the literature (Todd, 1959, Johnson and Finlayson, 1988) the term "conjunctive use" is often employed differently. In the view of these authors conjunctive use requires that water is actively transferred at an optimum rate from surface reservoirs to ground water storage. Surface storage supplies most annual water requirements while ground water reservoirs can be retained primarily for cyclic storage covering any series of years having below normal precipitation. Thus ground water levels would be lowered during a cycle of dry years and raised during a following wet period.

The difference in the definitions or uses of the term "conjunctive use" lies therefore in the transfer of surface water to the ground water systems. Despite technical difficulties

Table 1 Projected water demands Botswana (BNWMP, 1992) for the period 1990 - 2020 (amounts in MCM/yr)

	1990	2000	2010	2020
urban centres	21	45	72	103
major villages	8	22	35	52
rural settlements	7	11	15	20
mining and energy	23	36	56	64
irrigation	19	29	39	47
livestock	35	45	34	44
wildlife	6	6	6	6
total	119	194	257	336

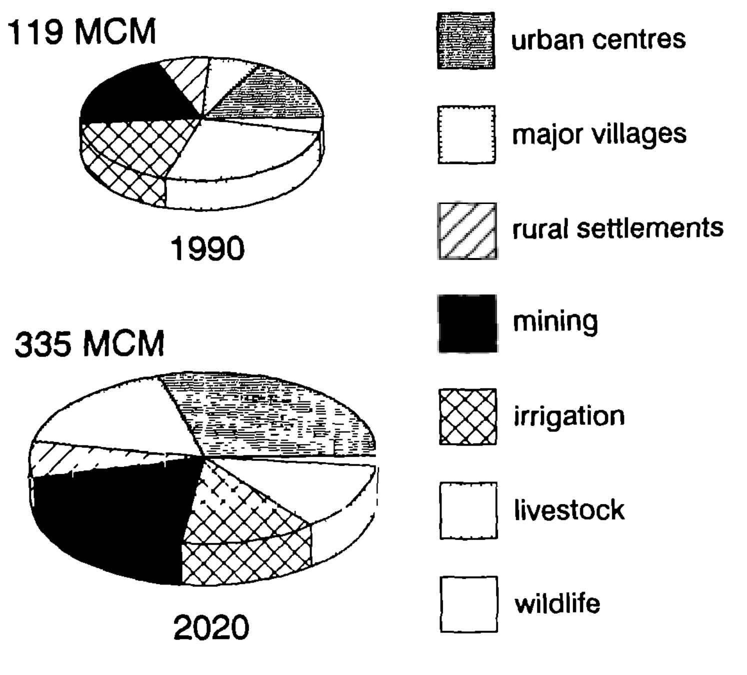

Fig. 1 Projected water demands for Botswana (1990-2020) after BNWMP, 1992.

associated with this transfer, or artificial recharge as it is usually called, Johnson and Finlayson (1988) contains many case studies describing the latter type of conjunctive utilization of water resources.

Combined use of large dams and wellfields is only possible in eastern Botswana. However, a large part of the population lives in small villages and depends for its water supply on local boreholes, ephemeral streams, small dams, haffirs, hand dug wells or roof catchments. It seems therefore appropriate to adopt in this paper a more holistic view of the term "conjunctive use" and include in the discussion the optimization of small scale water resources for the thinly populated parts of the country.

Moreover, in view of the fact that conjunctive use of water resources implies to a great extent optimization of the use of all available resources one could add other aspects, such as re-cycling and re-use of waste water, desalination, mixing of waters with different qualities to obtain an acceptable potable compromise, and designation of individual (low or high quality) water resources for specific purposes.

In this paper first a short overview is given of the different sources of water available to the population and the way these are utilized. Then specific rural area water supply problems are discussed, after which some aspects of the large scale eastern Botswana surface and ground water utilization plans are reviewed. Although the scope of this short paper evidently precludes a thorough discussion of all aspects, some suggestions for possible follow-up are presented in the last section.

UTILIZATION OF WATER RESOURCES OF BOTSWANA

Fig. 1 and Table 1, derived from the National Water Master Plan (BNWMP, 1992) clearly illustrate Botswana's water supply development challenge for the next 30 years. The total population is estimated to rise from 1.25 million to about 3 million by 2020. The increasing population coupled with economic development will triple water demands during that time span. The difficulties in making demand projections have already been discussed by Z. Makosha (this report) while J. Gould (this report) discussed the question whether it would not be wiser to try to reduce the demands in view of Botswana's limited resources. That the demand will rise considerably, however, seems beyond dispute.

Figure 2 shows the relative increases of surface and ground water components. The surface water demand is estimated to rise from 42 to 186 MCM/yr whereas the ground water contribution may rise from 76 to 140 MCM/yr. Fig. 3 illustrates the diversity of water supply sources in Botswana. It is obvious that large scale differences exist between the sources. A large dam with pipelines will require investment of millions of Pula while the ALDEP roof tank catchment (40 m^2 roof and 7 m^3 tank) costs about P 3000. Key issues in the development and optimization of water supply systems are efficiency in use and conservation of water resources at both ends of the scale.

Dam sites are generally poor because of Botswana's flat topography. The country's semi-arid climate causes high rates of evaporation leading to substantial losses from surface catchments and rivers are ephemeral with erratic flow except in the north of the

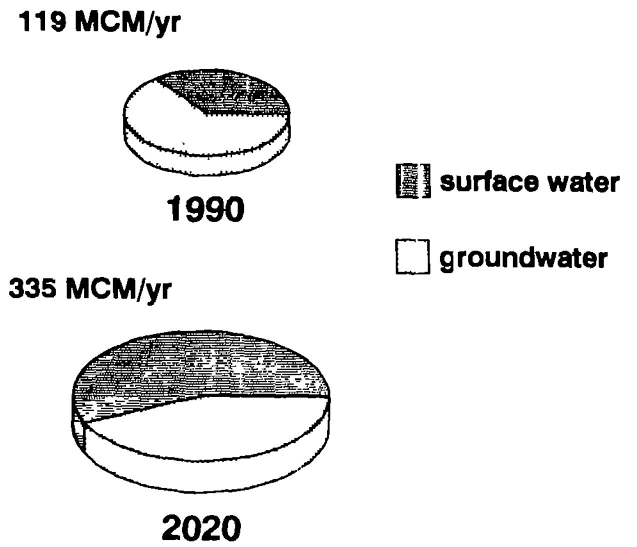

Fig. 2 Change in ratio of surface to ground water in the period 1990-2020 (BNWMP, 1991).

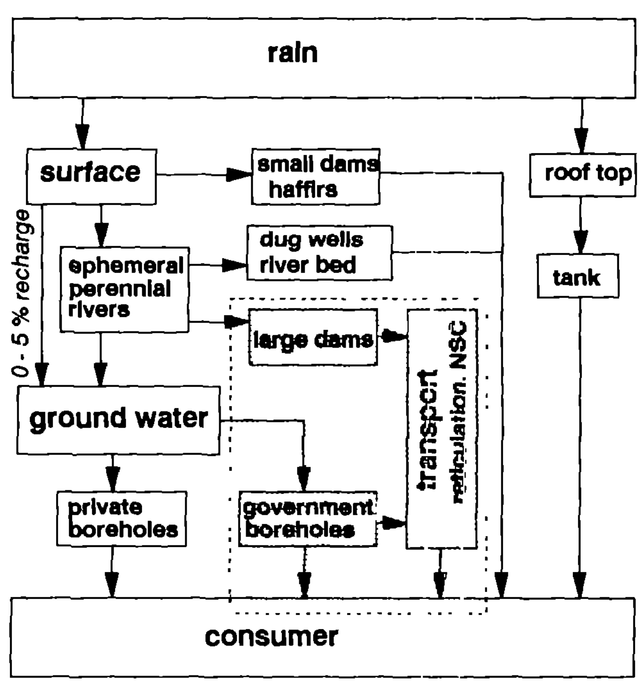

Fig. 3 Flow diagram of water sources in Botswana.

country. Ground water recharge varies from a few percent of the annual rainfall in the eastern part of the country to practically zero in the west. Long-term sustainability of ground water resources is therefore questionable and any large scale abstraction will effectively be mining the resource. Continued exploration for new ground water sources will be required in the foreseeable future and since aquifers may be far from demand centres development of the wellfields will need huge investments.

The main recommendations of the National Water Master Plan (BNWMP, 1991) roughly fall into two categories

- Provision of water for the main urban centres in eastern Botswana by means of a major transfer scheme, the North-South Carrier, with simultaneous construction of new dams and development of ground water resources along the carrier. This development corresponds to the shaded area of Fig. 3. The increased use of water in the urban areas should also lead to implementation of plans for recycling and re-use of waste water. Some of the major villages may be linked into the transfer scheme but most will have to be supplied from expanding ground water abstraction schemes in their immediate environment.

- Improvement of water supply for small villages and the scattered rural population. A systematic approach to technological advancement of low-cost water supply systems such as dug wells, roof top catchments, haffirs and small dams, combined with development of guidelines for settlement policy will hopefully lead to an improvement of water supply systems, water quality and reduction of the distance to the supply points. A Lands Area Water Supply Study (LAWSS, 1991) was commissioned by the Government of Botswana to study the problems of water supply to small villages and scattered rural population and make recommendations to improve the situation. Only a draft report is available at present and a decision from DWA is expected shortly.

VILLAGES, LANDS AREAS AND SCATTERED RURAL POPULATION

The problem of water supply to major villages has already been discussed in the papers by M. Hagos, F. Maunge and N. Taleyana (this report) and it is therefore not necessary to give a thorough discussion here. Generally, these major villages rely on wellfields with reticulation schemes constructed by the Department of Water Affairs. The responsibility for operation and maintenance may in the near future shift to a large extent from the Department of Water Affairs to the District Councils and the Ministry of Local Government, Lands and Housing. Problems regarding the optimization of water supply to these villages include

- the establishment of efficient operation, maintenance and repair procedures
- level of participation of local population in operation and maintenance
- the extent to which initial government investment can and should be recovered from water users

From an applied research and management point of view it is important to monitor the wellfields with respect to abstraction, water levels and quality. Locally acquired hydrogeological information should be transferred to the departments of Water Affairs and Geological Survey to obtain better understanding of the regional hydrogeology and long-term sustainability of the resources. With increasing independence of the District Councils in the operation of local water supply systems, it becomes more important to attach trained hydrogeologists to these Councils to ensure a multi-disciplinary approach. This will not only make monitoring of abstraction and quality easier, but will also facilitate future expansion of wellfields and siting of new boreholes.

Diagram 3 illustrates the diversity of water points used by the scattered rural population (SRP). The Lands Areas Water Supply Study (LAWSS, 1991) studied the distribution and use of locally available water sources in detail in five Study Areas (Fig. 4) and the results are summarized in Table 2. It is obvious that large differences exist between eastern and western Botswana areas. Because of the absence of ephemeral rivers with episodic runoff the inhabitants of Area 9 have to rely much more on direct rain catchments and public water supply (boreholes with stand pipes) than people in for example area 1. Present consumption rates do not seem to exceed 10 litre per person per day at present although an exact rate is difficult to assess as the water is shared between domestic needs and small livestock. The average distance to the nearest water point varies between one to four kilometres normally but goes up to between 10 and 20 km in times of drought. Because on average water is fetched twice daily, it is clear that considerable distances have to be covered each day. Moreover, water quality is generally poor with salinity and bacterial infection as major problems.

Because the small settlements and scattered rural population obviously represent a poor economic sector, difficult compromises have to be sought in trying to reduce the distance to the water points, upgrade water quality and improve technical reliability of water abstraction. Moreover, improvement is directly related to settlement policies and advancement of related infrastructure. In principle, targets for the next century include the following

- domestic <u>potable</u> water supply should reach 25 l/day per person
- water should be available for ten livestock units per day (450 l/day)
- potable water must be available within 2 km of individual residences (3 km is viewed as the maximum distance in remote areas)

Realization of these targets, however, depends on the answer to a number of elusive questions

- which technical methods for water collection and abstraction work best in a rural environment with limited economic resources ?
- in which direction is the balance between government involvement and private enterprise going to move in the next 30 years ?
- what socio-economic trends can be expected with respect to the scattered rural population ? Should settlement policies be determined by locally available water resources, or should water supply be guaranteed irrespective of cost and remoteness of area ?

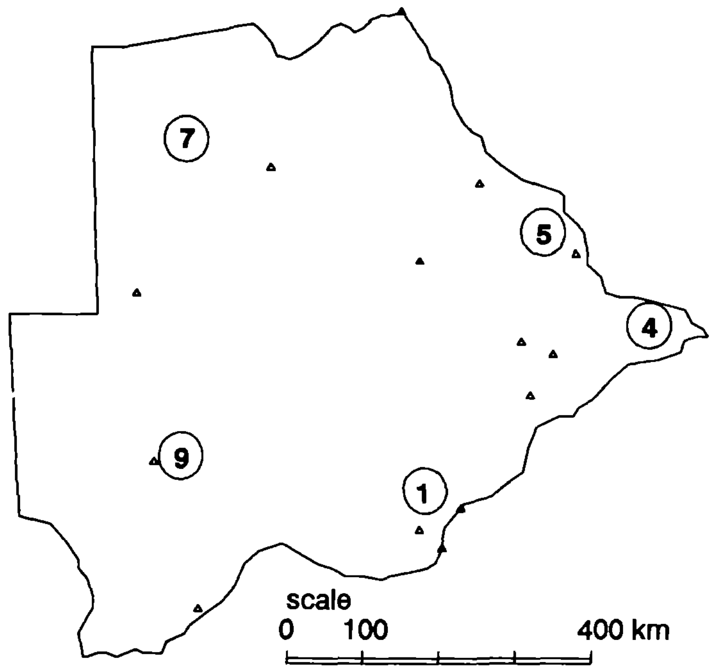

Fig. 4 Location map of the five LAWSS (1991) study areas in the Lands Areas.

Table 2 Main sources of drinking water for five rural areas in Botswana (source : Lands Areas Water Supply Study, 1991)

source	area 1 (%)	area 4 (%)	area 5 (%)	area 7 (%)	area 9 (%)
village	-	1.0	2.5	-	30
hand-dug well	15.3	21.7	24.8	27.7	21
dam	8.8	-	2.2	-	-
haffir	5.1	-	0.7	-	-
river surface	15.3	5.7	2.2	2.2	-
sand river	16.7	40.3	15.7	57.1	-
roof tank	0.3	-	0.5	-	-
underground tank	4.0	-	4.2	-	-
springs	5.5	-	8.6	6.7	-
stand pipe/bhole	28.9	23.0	25.5	8.4	46
other	-	8.3	13.0	-	3

LAWSS (1991) made a first attempt at solving this diversity of problems by employing Multi-Criteria Analysis (MCA). First the study identified criteria such as costs, energy, reliability, technical solutions, operation and maintenance, distance, economic impact, government involvement, implementation time, etc. By assigning sets of weight to these criteria, it was possible to study several scenarios through the use of Artificial Intelligence computer programmes. Results of these tests suggest that in general where possible a collection of smaller water points of varying nature meets the objectives for the scattered rural population better than alternatives with a central borehole.

However, the difficulty in producing a generally acceptable set of weights and the uncertainties still clinging to the existing designs of, for example, roof top catchments and dug wells make this a preliminary exercise. Before drawing final conclusions, it seems desirable to start pilot projects as was already suggested by LAWSS (1991). The diversity of the problems associated with the optimal water supply provision for the scattered rural population require a multi-disciplinary applied research and management approach. Finally, the use of MCA computer programmes in decision and policy making processes of this nature should be questioned and researched further and for validation contrasted with the outcome of more conventional approaches.

CONJUNCTIVE USE OF SURFACE AND GROUND WATER FOR THE LARGE URBAN CENTRES

As mentioned in section 2, the plans for the eastern Botswana water supply consist of developing a major transfer scheme, the North-South Carrier, with simultaneous construction of new dams and wellfields. Previous contributors (this report) have outlined its design and operation in detail. A further aspect of conjunctive use of dams and ground water is discussed in this section in relation to developments abroad.

Figure 5 illustrates the characteristic use of a dam; in this case the water supply of Shashe Dam (BNWMP, 1991) is used as an example. When the annual amount of water supplied by the dam (top diagram) is 24 MCM/yr about half of the water spills and another quarter evaporates. Only one quarter of the impounded water is therefore actually used. Shortfalls rarely occur under this abstraction scenario. Increasing the amount supplied by the dam to 48 MCM/yr (bottom diagram) leads to a substantial decrease in spillage but also to an increase in shortfall periods, or years when the dam cannot deliver the required amount of 48 MCM. Fig. 6 illustrates these elements on a time scale. The short-fall periods have to be augmented from other sources to ensure a steady water supply. It was originally suggested in the National Water Master Plan Study that the Palla Road wellfield could augment the surface sources and it was proposed to completely mine this resource during the planning period (Fig. 7). The exact date of depletion depends of course on climatic conditions and completion dates of new dams.

Although new wellfields could probably be developed after that, it may perhaps be possible to avoid depletion of aquifers by introducing the element of cyclic storage through artificial recharge methods. The advantages of such cyclic storage, or "groundwater banking" as it is called in the Unites States, is shown in Fig. 8. In addition to the water supplied by the dam (48 MCM/yr) some more water is abstracted during

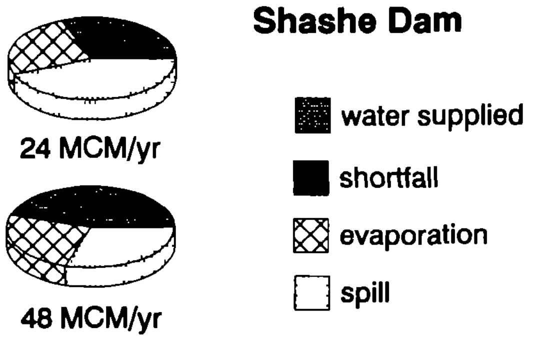

Fig. 5 Water supply from Shashe Dam (BNWMP, 1991).

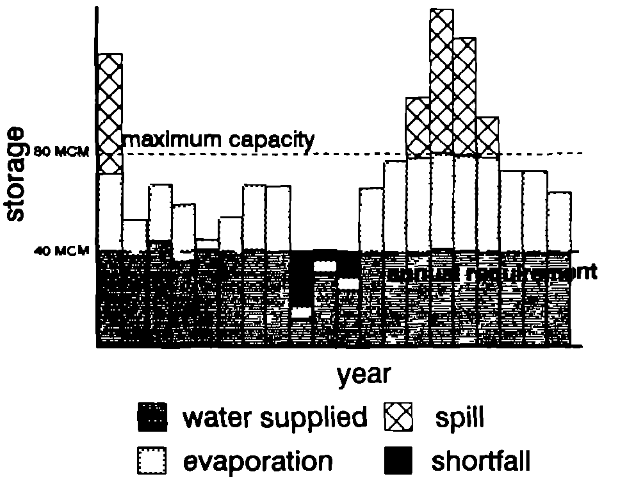

Fig. 6 Example of water balance for a hypothetical dam as a function of annual inflow.

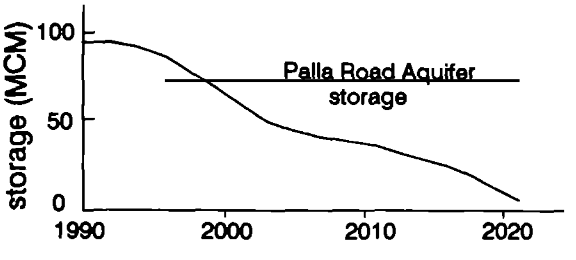

Fig. 7 Decrease in storage at Palla Road Wellfield during first 30 years of NSC operation (after BNWMP, 1991).

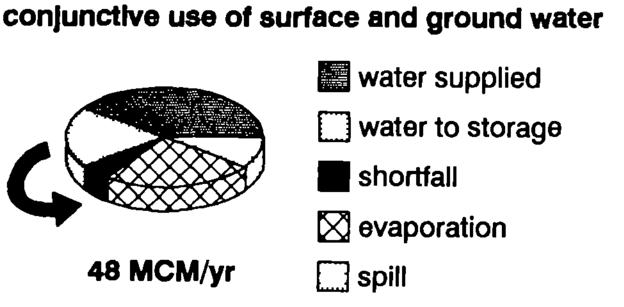

Fig. 8 Cyclic storage leading to more efficient dam use.

wet years which is then stored underground. This will lead to a decrease in spillage and an increase in shortfall years. However, in dry years the shortfalls are covered by abstraction of the stored ground water. This procedure leads to more efficient use of dams while at the same time protecting ground water resources.

The main problem in implementing such conjunctive management schemes lies in the technical difficulties of artificial recharge. However, many projects over the entire world have been in operation for a long time now and results seem to be encouraging. Madrid (1988) estimated that in the State of California alone 2160 MCM is recharged on an annual basis which corresponds to about 11 % of the total ground water abstraction in that state. Glenn (1988) and Diede (1988) describe the High Plains Ground water Demonstration Program comprising 21 projects in 17 states with a US Government funding of US $ 25 million for a period of 5 years. Kendall and Sienkiewich (1988) describe a programme to develop 600 MCM storage in Southern California for use in times of drought by the year 2000 (at present this storage is 120 MCM). While artificial recharge has not been tried systematically on any scale in Botswana, successful implementation of such schemes would lead to more efficient use of dam water and protection of the scarce and vulnerable ground water resources. It is therefore recommended to further study possible application of artificial recharge methods in Botswana in the framework of the eastern Botswana transfer system.

DISCUSSION

Problems associated with the intended improvement of water supply for the scattered rural population, major villages and urban centres fall into several categories

- In many cases answers to technical problems are not clear or cannot be given at all. For example : Is artificial recharge in Botswana technically feasible or not ? What is the best way to construct a durable low-cost roof tank catchment ? How can hand dug wells be improved upon best ? Are the ground water resources around the major villages sustainable or not ? What is the impact on environment of technical choices decided upon ? The answers to these problems can only be given by applied technical and scientific research requiring concerted, long-term efforts.

- The difficulty in obtaining clear technical answers is further compounded by the problem to quantify socio-economic trends and to assess the degree of government involvement required to guarantee sound development of the country's different water supply sectors.

- Successful operation of complex large-scale water transfer schemes depends on well trained middle level technical staff. Success of water conservation and direct rain catchment schemes depend on the awareness and involvement of the general public. To train high level professional staff alone is not enough.

To deal efficiently with these problems it seems important that multi-disciplinary applied research and management approaches are stimulated and that links between institutions and departments involved in the water sector are strengthened. Specifically, there seems to be room for improvement in the following aspects

- Although the monitoring of water levels, dam levels, runoff and water quality is now well established for the larger dam and ground water projects, instrumentation of the smaller projects for the Rural Water Supply seems to be lagging behind. Small scale and site-specific projects such as, for example, roof catchment or haffir design can only be evaluated properly when accurate data are available.

- Co-ordination between Government Departments (DWA, DGS, MLGLH) and other Institutions such as RIIC, BTC, Polytechnic and UB should be strengthened in regard to applied research and technical problems. The work by the Blair Research Laboratory in Zimbabwe on Rural Water Supplies and Sanitation outlined by Morgan (1990) is a clear example of what applied research may mean in this respect.

- While the future development of the relation between Government and Private Sector is difficult to predict, Government should push ahead with small well-designed projects stimulating applied research and technical development. Attention should be focused on clear objectives, development of site-specific and flexible designs and improvement of durable low-cost designs.

- Artificial recharge through spreading basins or injector wells requires close co-operation between water engineers, hydrogeologists and infiltration plant operators. There is no experience with such projects in Botswana. Quoting Bouwer (1988) : "Recharge systems are site-specific and what works well in one place may not be the best in another. Thus, when artificial recharge of ground water is considered in areas where there is no previous experience with such systems, it is always desirable to start with a small project to obtain local experience with artificial recharge of groundwater and to develop design and management criteria for the full-scale project". Potential research areas for such projects in Botswana are, for example, the Shashe wellfield in Maun or some area near the Palla Road Wellfield within the general framework of the Eastern Botswana Water Supply systems.

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Note : If not mentioned explicitly in this list the papers are quoted from the Anaheim Symposium Report on Artificial Recharge.

EFFLUENT RE-USE, A POTENTIAL WATER RESOURCE FOR MULTI-PURPOSE UTILISATION: GABORONE CASE STUDY

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ABSTRACT

The 1988 pre-investment plan for Gaborone estimated the total potable water demand for the city will reach 63000 cubic metres/day by the year 2010 with a corresponding level and yield of waste water generation at a 90% return factor to the sewers producing 57000 cubic metres/day.

The rapid growth potential in the city of Gaborone and indeed the impact of the Accelerated Land Servicing Programme would together constitute a heavy demand on our potable water in the region, resulting in the significant depletion of water resources and leading to a reciprocal increase in the production of waste water.

To ensure adequate provision of water to Gaborone additional water is imported from the Molatedi Dam in South Africa and the Metsemotlhabe Transfer Scheme from Bokaa Dam. Both Molatedi and Metsemotlhabe systems are within the same hydrological regime and are prone to the same drought episodes.

With this phenomenon in mind, the Gaborone Effluent Re-use Study demonstrates that whether or not drought occurs in this region, waste water production is guaranteed. Following extensive evaluations and explorations in resource recovery potential,the study shows landscaping and restricted agricultural activities are possible. In the long term the study recommends effluent recycling of about 11000 cubic metres/day back into the total water regime provided cost effective treatment options are put in place.

Gaborone's Effluent Re-use Case Study demonstrates great potential for the economic viability of waste water recovery.

BACKGROUND

In Gaborone, a city with limited water resources and continuous drought episodes,effluent re-use should be considered a potentially reliable source for sustainable multipurpose use. The growth potential within the City of Gaborone and indeed the impact of the Accelerated Land Servicing Programme will together,continue to place heavy competing demands on the present and future meagre water resources.

The 1988 pre-investment master plan for Gaborone predicted the average potable water demand for the City and by the year 2010 to be 63000 cubic metres per day, with a corresponding waste water production level generation reaching 57000 cubic metres per day (S.A.G.P 1988).

Also comparative analysis of urban, peri-urban and major village water resources, between the years 1990 and 2020 reflected Gaborone's waste water production level as providing significant amounts to support effluent re-use (BNWMP 1991). The table 1 below presents water generation scenarios for period 1990-2020:-

Table 1. Estimated return flows (1000 cubic metres/day)

Town/Village	1990	2020
Gaborone	14.4	103
Francistown	5.0	36
Selebi Phikwe	4.4	21
Lobatse	3.2	8.2
Jwaneng	1.3	4.0

Source : Botswana National Water Master Plan Volume 9- Sanitation (March 1991).

Besides the quantitative estimates above,in a celebrated effluent re-use study dedicated to the City of Gaborone,waste water production was correlated to the water consumption patterns in Gaborone, Mogoditshane, and Tlokweng since they all belong to the same water works area.The study concluded that these three areas would produce substantial amounts of potentially exploitable waste water.To advance the concept of multi-purpose utilisation, waste water production levels and predictions will be restricted only to Gaborone as displayed in Figure 1 and Table 2.

One most important conclusion that can be deduced from Figure 1 and the Botswana National Water Master Plan predictions is that whether or not there is drought in Botswana,"waste water production is inevitable".

EFFLUENT AS A VALUABLE WATER AUGMENTATION SOURCE

The regional water resources serving Gaborone are not sufficient hence forced importation of water from other regions. In the evaluations on the feasibility of effluent re-use for Gaborone the conclusions reached indicate that recycling for multi-purpose use possibly defer the first stage of the North South Carrier and could certainly delay its duplication.

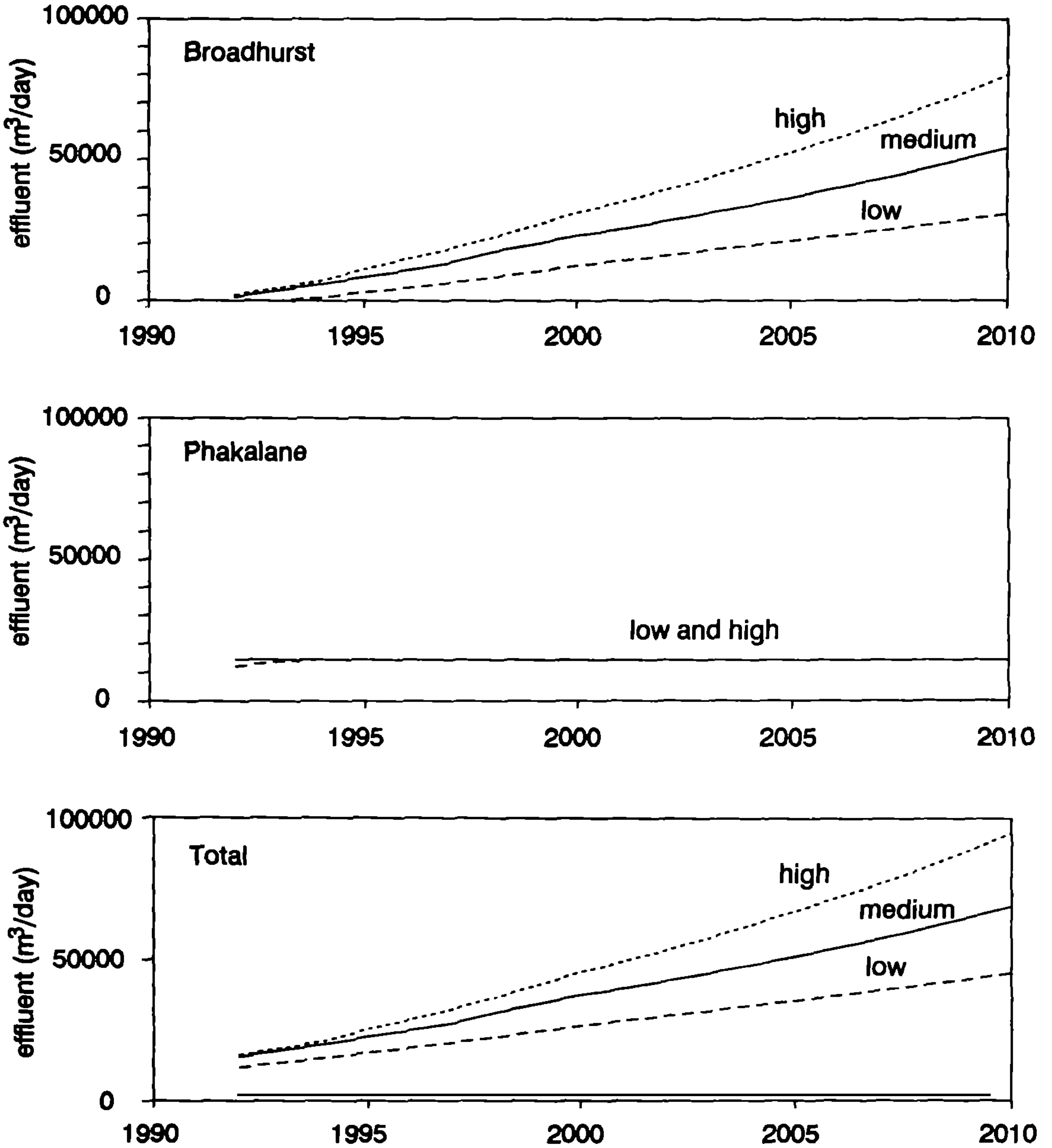

Fig. 1 Projections of effluent availability.

Projections from the Phakalane Waste Water Impounding Reservoirs show the average daily effluent production level to be 14,000 cubic metres per day. Isolating an allowance committed to the Sebele Agricultural College, Golf Club,and amounts reserved for the city's landscaping activities gives a maximum available effluent for multi-purpose use as 11,000 cubic metres per day. The effluent available for recycling purposes is estimated to be 4,200,000 cubic metres increasing to 13,100,000 cubic metres per annum by year 2010 and therefore representing a 47% waste water increase. It is evident from the empirical illustration above that waste water production and reclamation may no longer be ignored. Against the background of expensive water transfer schemes,there is a resource that can be obtained within the borders of Botswana and at no cost to the Government: Waste Water. It is cheap, available in Botswana and is not adequately exploited.

The thesis governing waste water utilisation encourages technology and reclamation for economic reasons to be advanced in a responsible and environmentally -friendly manner by adopting the following mandates:-

(a) Exercising vigilance against the short and long term harmful effects on the environment.

(b) Conserving water resources by encouraging waste water use to augment the limited resources.

(c) Understanding the basic principles and the functional efficiencies of the conventional waste water treatment systems to achieve the effluent quality that best supports effluent recycling.

A waste water management and reclamation strategy in Botswana may also be justified by the following specific reasons:

(a) Given the erratic rainfall and the long drought episodes,maximum utilisation of the available waste waters increases reliability of the scarce resources.

(b) Waste water reclamation reduces dependency on water imported from other countries.

WASTE WATER RE-USE AND ENABLING TECHNICAL GUIDELINES

To advance the concept of effluent re-use the D.W.A. established conventional guidelines for treated effluent discharge into perennial and ephemeral streams and in particular set up parameters and levels of treatment required to support restricted and unrestricted agricultural potential.

In its immediate and interim phase,and in compliance with D.W.A. guidelines,the Gaborone Effluent Re-use Case Study recommended feasible treatment methods and efficiencies necessary to provide a final waste water product that satisfies all environmental considerations.

The following practical remediation measures were suggested :-

(a) De-sludging the ponds periodically to continuously recover the original hydraulic design and treatment capacities.

(b) Trade effluent controls and administration based on the polluter-pays principle to encourage pre-treatment of high strength industrial effluents.

(c) Effective reduction of algae and therefore a guaranteed exploitation of the disinfection properties from the sun's ultra violet treatment.

(d) Cataloguing appropriate cropping activities and establishment of crop water needs.

(e) Reconnaissance surveys of irrigable areas to monitor the sodium absorption ratios to ensure a soil chemistry that supports present and future agricultural production.

COST EFFECTIVENESS ANALYSIS FOR GABORONE'S EFFLUENT RE-USE PROPOSAL

Several evaluation criteria on cost effectiveness analysis exist,however,to support the concept of effluent re-use, this paper restricts the definition of such assessments to the following :

- Provision of the water quantity demanded by farmers around Gaborone.
- Meeting the water quantity demanded by the present and future industries.
- Satisfying the water quantity and quality demanded for landscaping by the Gaborone City Council.
- Staying within the cost effectiveness guidelines of the D.W.A.and supporting the societal benefits accruing to the residents of Gaborone and peripheral villages.
- Meeting the water quantity requirements for W.U.C. for reclamation towards potable use.
- Supporting extensive agricultural research projects at Sebele College.
- Multi-purpose use of the total sewage effluent produced in Gaborone.

The effective re-use of effluent would benefit farmers by raising their standard of living, improving their incomes and encouraging developments.The differential costs which would result from pumping, construction, conveyance and storage are recognised but, the assumption built into the re-use model is that the benefits of effluent exploitation far exceed the disadvantages.

Table 2. Cost effectiveness criteria for effluent re-use.

System	Definition	Possibility for Environmental Damage	Contribution to Future Water	Quality of Exchange Ground Water	Percentage Effluent Used	Flexibility for Deviation	Risk of Losses	Possible Public Acceptance at Proposal Time
I	Quantity demanded by farmers	Small for good effluent quality Big for poor effluent quality	Good subjet to hydrological determinations	Good for good effluent quality Poor for poor effluent quality	Proposed apportionment 25	Rigid	Big is effluent quality poor Available/ Diminishing	Excellent
II	Quantity demanded by industries	None	With rigorous recycling by industries - little	With recycling by industry - none	Proposed apportionment 15	Good particulary for food industries	Fair	Excellent for non-edible forms of industry. Bad for edible forms
III	Quantity and quality for G.C.C.S. landscaping	Small for good effluent Big for poor quality	Reasonable subject to hydrological determinations	Good for good effluent quality Poor for poor effluent quality	Proposed apportionment 20	Good	Fair	Good with good quality efffluent
IV	Cost effective guidelines - W.U.C	Expenditure incurred by WUC for effluent reticulation recoverable from tariffs						
V	Quantity demanded of W.U C	If poor and heavily polluted effluent hazardous to health	40% of treated effluent	Good if used for irrigated agriculture	Proposed apportionment 40	Good	Fair if effluent re-use politically acceptable	Very poor hence effective sensitivity analysis essential
VI	Total utilisation of effluent	Small for good quality effluent Big for poor quality effluent	Substantial through - W.U.C. - Groundwater Recharge (Irrigation and direct aquifer recharge)	Good for well treated effluent	100 20 Lost through evaporation	Good within investment magnitudes Rigid where investments are heavy	Big if effluent is poor - effluent becomes unavailable or diminishes	Variable according to specific uses but utimately negotiable

The above table indicates quite clearly that properly treated waste water has great multi-purpose re-use potentials. However, because of possible public objections effluent re-use limitations will persist but only in the short term.

RE-USE CONSTRAINTS

The positive correlation between the findings of the author in his previous research and indeed those from the Gaborone Effluent Re-use case study indicate the following as possible effluent re-use constraints:

- Socio-cultural attitudes and behavioral tendencies scepticism on the integrity and the credibility of the resource .

- Lack of distribution networks to possible users

- Inadequate campaigns and strategies for marketing the waste water product.

- Lack of Environmental Impact Assessments supporting re-use experiences in Botswana.

- Lack of Government's Policies directing resources conservation and maximum recovery of effluent to support economic incentives.

In support of the technical cost effectiveness re-use thesis revisited Table 3 below, analyses of the samples from raw water taken from Shashe Dam, Nnywane Dam, Gaborone Dam and the composite samples of effluent taken from the Broadhurst Waste Stabilisation Ponds and certainly suggest evident differences in the bacterial and pathogenic content. Further, contrast in heavy metals between W.H.O. Guidelines and those from Botswana seem small. With tertiary treatment of effluent and indeed with effective removal of pathogens organisms and bacteria through Ultra Violet and other disinfection mechanisms, waste water could be recycled beneficially adding to the regions water resources.

DISCUSSION

Plagued by chronic shortage of water, Windhoek, the Capital City of Namibia reclaims more than 13% of potable water from sewage. Certainly long term demonstration and sensitization programmes to break the social barriers and intransigent attitudes would be necessary here in Botswana before success stories similar to Windhoek's could be realised.

In Botswana, successful waste water re-use modelling occurs in Lobatse, where lucerne is produced to feed the animals; in Gaborone's restricted agricultural productivity; in the seed multiplication activities at the Sebele Agricultural College; and in the maintenance of the golf course in the city.

Table 3. A comparison and contrast between raw water samples and final effluent.

Parameter	W.H.O. Guidelines	Botswana Guidelines	Shashe Dam (W.U.C.) 1991*	Nuane Dam (W.U.C.) 1991*	Gaborone Dam (W.U.C.) 1991*	Composite samples of effluent (Broadhurst) 1989**	Remarks of effluent results against W.U.C. and Botswana guidelines
pH Value	6.5 - 8.5	6.5 - 9	7.3	7.73	7.91	9.3	- Effluent pH slightly above guidelines
Conductivity, ml/m 25 C			12.3	15 0	10 4	475	- Well above WUC's results
Manganese, Mn	0.1~	0 1 - 0.5~	<0.01~	<0.01~	<0 01~	<0.01	- Within guidelines and WUC's results
Phenolic Compounds	0 001~	0.005 - 0.01~	<.001~	<0 001~	<0 001~	—	(Both WHO and Botswana)
Chromium, Cr	.05~	0.1~	<0.1~	<0.1~	<0.1~	<0 01~	- Within Botswana guidelines
Selenium, Se	.01~	0 01 - 0.05~	<0.01~	<0 01~	<0.01~	—	
Nitrate, NO_3	10~	20~	1.8~	0.5~	0.4~	9.01~	- Within W H O. guidelines
Floride, F	1.5~	1.5 - 2.5~	0.4~	0.8~	0.5~	—	
Orthophosphate, PO_4	—	1.5~	0.12~	0 10~	0 4~	—	
Dissolved iron, Fe	0.5~	1 0~	0.91~	4.4~	0.70~	<0.01~	- Within W H O. guidelines
Copper, Cu	1 0~	1 0~	<0 01~	<0 01~	<0 01~	<0 01~	- Within W H O and Botswana guidelines
Cyanide, Cn	0.1~	0 1~	<0.05~	<0 05~	<0.05~	—	
Cadmium, Cd	0 005~	.005 - 05~	<0.01~	<0 01~	<0 01~	<0 01~	- Compares with W.U C.'s results
Lead, Pb	0.05~	0 05~	<0 01~	<0 01~	<0 01~	<0 01~	- Compares with W U.C.'s results
Zinc, Zn	5 0~	5 0~	<0 01~	<0.01~	<0 01~	<0 01~	- Compares with W.U C 's results
Arsenic, As	0 05~	0 1 - 0 5~	<0 01~	<0 01~	<0.01~	—	
Mercury, Hg	0.001~	0 0001 - 0.02~	<0.001~	<0 001~	<0.001~	<0 01~	Within Botswana guidelines
Aluminium, Al			<1~	<1~	—		
Heavy metals						<0.01~	- Includes Ni, Mi, Pb, Ci, Cd, Zn, Cu, Fa, Hg
B O D	—	20 - 30~	—	—	—	80~	- Effluent BOD above guidelines Botswana
C.O D	—	75~	—	—	—	120~	- Effluent COD above guidelines Botswana
S S	—	As in TDS 1 5	—	—	WUC's Aug 170 (1972-1973)	30~	- S S above Botswana guidelines
Faecal coliforms	—	100 - 500/100 ml	—	—	—	500 - 5000	- Above Botswana guidelines
Total coliforms	10	5000 - 20,000/100ml	—	—	—	>7000	- Well above but within Botswana guidelines
Dissolved oxygen	—	75% of SAT CONC	—	—	—	55% of SAT CONC	- Slightly below Botswana guidelines
Chlorides	600~	600 - 1000~	—	—	16mg/l ('83)	59 6~	- Much better than W H.O and Botswana guidelines
Ammonia (Free & Saline)		1 - 10	—	—	—	12~	- Within Botswana guidelines
Sulphur	—	—	—	—	—	39.2~	
S.A R.	—	—	—	—	—	0.323	

NOTE: ~ = mg/l

* Source: McLachlen & Lazar (Pty) Ltd, Johannesburg, (South Africa, 1991)

** Source: Sir Alexander Gibb & Partners, Gaborone (1989)

W.H.O Guidelines adopted by D.W.A. in 1988

Botswana Guidelines (D.W.A.) 1988

- Denotes not tested for/evaluated

In the City of Bulawayo,in Zimbabwe,irrigated woodlot plantations and even the production of animal feeds to practical economic proportions is a reality.

In its determination of a water resources development strategy inclusion needs to be made for waste water exploitation. The experiences and the evidence presented in this paper indicate that waste water can be transformed into a viable economic good.

Finally, constraints in the re-use model identified as social barriers, a lack of technological preparedness, and public policy deficiencies in Botswana need to be addressed in order to advance the multi-purpose use of effluent.

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WASTE WATER RE-USE AND CULTURAL EUTROPHICATION: A CASE STUDY.

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ABSTRACT

This paper describes a case study of eutrophication of a reservoir, Lake Chivero (formerly McIlwaine) in Zimbabwe, resulting from inflow of treated domestic and industrial sewage effluent. The paper also described efforts employed to manage the problems arising from the excessive nutrient loading. Attempts to reverse the trend of eutrophication involved diverting treated sewage effluent away from streams flowing into the reservoir as well as upgrading sewage treatment to produce less polluting effluent. The lake showed signs of recovery but of late the problem of eutrophication seems to have recurred, this time due to increased inflow of nutrient-rich untreated storm waters and, to some extent, improperly treated sewage effluent.

INTRODUCTION

About 99.9% of raw domestic and industrial sewage is made up of water. Treatment of sewage separates the solids in sewage from the water. The effluent from sewage treatment works is mostly water. The quality of the effluent varies according to the efficiency of the treatment processes employed. Good quality effluent is one that does not contain infective bacteria nor high concentrations of nutrients such as nitrates and phosphates. When discharged in natural waters, such effluent result in over-nitrification of the receiving waters, the main cause of eutrophication of lakes and reservoirs.

Eutrophication refers to the natural aging process of lakes. As a lake ages, it fills up with sediment, reduces in volume resulting in increasing concentrations of nutrients and, subsequently, increased biological productivity. This is normally a slow process lasting several hundreds or thousands of years. The process can be quickened by human activity resulting in the attainment of the eutrophic state in a much shorter time. Where the process of eutrophication is accelerated by human activities, the process is then termed "cultural eutrophication".

Such human-induced eutrophication of lakes and reservoirs which receive water with high nutrient concentrations has been well-documented (Ryding and Rast, 1984). This phenomenon is increasing in most countries as a result of more intensive use of artificial fertilisers, increases in discharge of treated or improperly treated domestic and industrial sewage effluent.

Manifestation of eutrophication

The most obvious manifestation of eutrophication is the prolific growth of algae and/or aquatic macrophytes. Algal blooms associated with eutrophication usually lead to odour, colour and taste problems in drinking water. Purification of such waters becomes much more expensive and time-consuming as more chemicals are required to deal with these problems.

Other not-so-obvious consequences of eutrophication include:
- changes in species composition
- reduction in biodiversity
- increase in concentrations of algal toxins
- deoxygenation of water
- increase in concentrations of iron and manganese
- exacerbation of parasitic diseases such as schistosomiasis, onchocerciasis and malaria (Rast and Ryding, 1984).

In arid or semi-arid environments, water is vital resource which needs to be conserved. Conservation measures may include recycling or re-use of waste water. Southern Africa is one of those areas where water availability is not evenly distributed both in space and in time. Recycling of waste waters is seen as one of the most significant ways of conserving water. However, where this is done, it is not without problems. In Zimbabwe, the City of Harare's waste water management and its major source of water, Lake Chivero, provide an illustrative case study.

The Lake Chivero Case Study:

Lake Chivero (formerly McIlwaine) is one of the two major sources of water for Harare, the capital city of Zimbabwe. It is one of several reservoirs that have been created by the damming of the Manyame river. The lake has a catchment area of ca. 2230 km^2. The city of Harare and the town of Chitungwiza are both situated upstream of the lake (Fig. 1). Urban developments constitute more than 10 % of the lake's catchment area. Some features of Lake Chivero are summarized in Table 1.

Table 1. Some morphological characteristics of Lake Chivero.

Characteristic	
Maximum depth	27.4 m
Mean depth	9.4 m
Maximum width	8.0 km
Mean width	1.7 km
Length	15.7 km
Surface area @ FSL	26.3 km^2
Volume @ FSL	250 x 10^6 m^3
Catchment area	2227 km^2

Treated sewage effluent from the city of Harare's two main sewage treatment works used to flow into the lake through two streams, Marimba and Mukuvisi. Domestic sewage and industrial sewage were treated using the activated sludge and biological filter method. While the effluent was free of pathogenic bacteria, it contained high concentrations of nitrate and phosphate nutrients.

Surface run-off from the city collects in storm water drains which empty into streams flowing into the lake. The run off is not treated. Similarly poorly treated sewage effluent from the town of Chitungwiza and run off from that town ultimately flow into

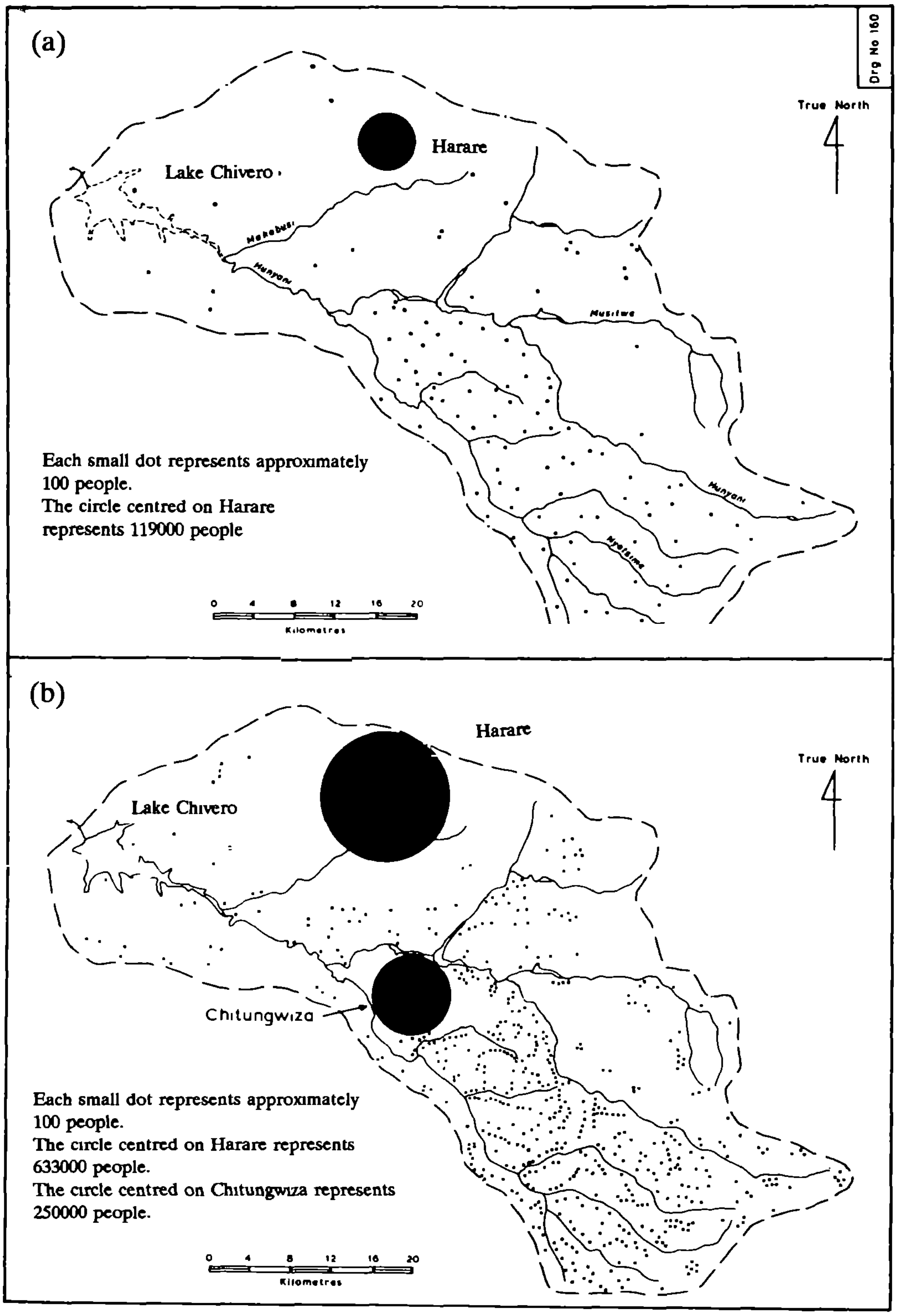

Fig. 1 Lake Chivero and its catchment

a. Population distribution in 1951

b. Population distribution in 1979

The current population for Harare is ca. 1.5 million and for Chitungwiza ca. 1 million people.

the lake. In the early seventies, the lake manifested as being highly eutrophic. An exotic floating macrophyte, *Eicchornia crassipes* (water hyacinth) covered much of the lake's surface. Blooms of blue green algae, mainly *Microcystis* spp. were frequently encountered.

At the time water was first drawn from Lake Chivero in 1953 and for the first five years, the raw water was of relatively good quality and easy to treat (McKendrick, 1982). To treat the water for turbidity, alum was added at average rates of 24 mg l^{-1} and 35 mg l^{-1} in the dry and rainy seasons respectively. Algal blooms in the early sixties necessitated the increase of the alum dosage to 45 mg l^{-1}, at one stage as much as 75 mg l^{-1} was used. As more and more alum was used in the treatment process, this interfered with the filtration process, sand filters had to be back-washed more frequently, every 6 - 8 hours.

When the lake thermally stratified in the warm season, there was no oxygen at depths greater than 9 m. There are two intake levels for raw water, one at 7.5 m and the other at 14 m. The one at 7.5 m was abandoned because of high densities of algae and high pH caused by the algal blooms. However, lack of oxygen at 14 m resulted in release into solution of iron and manganese which did not precipitate during flocculation and sedimentation because of the short retention time in the treatment works which did not ensure complete oxidation before filtration (McKendrick, 1982). It was, in fact, better to draw water from 7.5 m than from 14 m.

Under eutrophic conditions, blue-green algae usually proliferate. The dominant species in the Lake Chivero blooms were *Microcystis* spp. *Microcystis* sp. has been known to produce potent toxins, e.g. dogs and sheep died soon after drinking water in a reservoir which was experiencing a *Microcystis* bloom (Mason, 1991). It has been suggested that outbreaks of some enteric diseases, especially among children in Harare, could have been linked to effects of some toxic algae associated with the algal blooms that occurred during the period of eutrophication.

Measures taken to avert the problem of the pollution of the water source and its eutrophication involved (i) diversion of treated sewage effluent from the streams draining into the lake and (ii) installation of very expensive but efficient advanced waste water treatment processes which discharge effluent of "good" quality.

All the effluent from biological filters collects into reservoirs from where it is pumped to 3 400 ha municipal farms to irrigate pastures and crops. About 1 400 ha of this is arable and irrigable. Maize was produced in summer while wheat was irrigated in winter. The effluent, it was believed, would eventually trickle into the streams and lake after percolating through the soil, losing the nutrients in the process. Pasture irrigation resulted in ±75 % removal of nutrients, even in the rainy season. In the early eighties, the farm had 5376 head of cattle.

Use of treated sewage effluent for grazing pastures also had some attendant veterinary problems. The lush pasture was ideal habitat for a variety of pests and disease carrying vectors. The livestock had to more frequently orally dosed for liver fluke and other intestinal parasites and vaccinated for diseases such as rift valley fever, lumpy skin, vibriosis, contagious abortion and enterotoximia (McKendrick, 1982).

The practice of not discharging effluent from trickling filters into streams was made mandatory by the promulgation of Water (Effluent and Waste Water Standards) Regulations, 1977. These together, with Public Health (Effluent) Regulations, 1971, provided and enabling legislative environment that ensured that only effluent of a "good" quality could be discharged into the reservoir and its tributaries. The Water (Effluent and Waste Water Standards) Regulations, 1977, govern the quality of effluent or waste water that may be discharged into natural water courses while the Public Health (Effluent), 1972, prescribe the standards of effluents from sewage treatment works for use in crop irrigation.

Following these measures, there was an observable improvement in the quality of water in the lake, i.e the raw water going into the water purification plant. These measures were put into place in the late seventies. However, since these measures were put into place the population of Harare has soared to over one million inhabitants while that of Chitungwiza has grown to just below one million. Industry has also grown rather steadily since then. These include breweries, manufacturers of artificial fertilisers, detergents and other chemicals. Surface run off and storm water discharge still do not undergo treatment. As the cities' populations grew so did the volume of domestic and industrial sewage needing to be treated. The volume of raw sewage rapidly exceeded the design capacities of the sewage treatment works, which are continuously being upgraded. The upgrading usually lags behind the increase in capacity of raw sewage.

It was not long after the measures taken in the late seventies appeared not to be paying any dividends with regard to eutrophication control on Lake Chivero. Drought in 1982-83 reduced natural stream inflows to a minimum. This meant that sewage effluent from the cities did not receive previous levels of dilution. Lake levels dropped rapidly with the consequence that nutrient concentrations in the lake increased. A new eutrophication phase was experienced in the late eighties manifesting as explosion of water hyacinth on the lake's surface. In early 1989, the weed was estimated to cover more than 25% of the lake's surface and covered the whole surface of Manyame river for more than 5 km from the lake.

There were problems with water intake from the lake to the water treatment works with intakes being blocked. The quality of raw water deteriorated again increasing the cost of purification. In summer of 1989, the lake spilled for the first time after a long while. The floating weed was carried with the spill water and covered the whole surface of the river for about 1 km downstream of the dam. Some pipes which carried irrigation water from the lake spanned across the river supported by reinforced concrete beams. Both of these crumbled under the pressure of the piling weed. The lake failed to perform most of its previously normal functions: source of drinking and irrigation, recreational boating, yachting, commercial and recreational fishing. There were more people visiting the lake just to marvel at the weed problem.

Meanwhile administrators and scientists debated over the most practical solutions. One school advocated chemical spraying of the weed with biodegradable herbicides as a means of eradicating and controlling the weed. This was vigorously opposed by another school which argued that most of the proposed herbicides were known to be carcinogenic. Spraying would pose dangers to health since the lake was the major source of drinking water for the capital city. They proposed that the weed be removed mechanically. The opponents of this argued that mechanical removal would be effective in the immediate term as the weed was expanding at rates faster than it could be physically pulled out. Another proposal was the introduction of a beetle, *Cytobergus* sp., which is known to forage on the weed as a means of biological control. Opposition to this was based on the concern that since the weed is exotic and the beetle is also exotic, what would happen if the beetle turned to be a pest since there were no likely natural enemies?

Yet another proposal was to use the weed as livestock feed or for making paper. These proposals were opposed on the premise that such uses of the weed required that the weed should always remain there for the new "industries" to remain viable. Besides the weed, it was argued, has very little biomass, since most of it is air contained in floatation devices.

Ultimately the national President declared the problem was a national disaster after the visiting the lake. All measures necessary to avert the "crisis" were then to be taken. Authority was given to spray the weed with glyosate and to complement the spraying with mechanical removal. At the same time the beetle was also introduced. The weed was rapidly brought under control. The weed killed by spraying sunk to the lake bottom where it is decaying. The decaying weed is causing an increase in oxygen demand. The bottom waters are likely to be anoxic leading to incomplete decomposition of the massive quantities of organic matter from the sinking weed. It will take some time before the lake's water is "clean". Meanwhile the water treatment plant switched to draw more raw water from downstream Lake Manyame (formerly Darwendale).

The main problem in the Lake Chivero case study is that efforts were applied not at solving the nutrient supply problem, but at solving the problem of its effect. The weed problem is a result of the nutrient loading. Unless the causal factor, nutrient loading is addressed, the problem is likely to persist. To achieve the desired result, Chitungwiza town Council needs to install more efficient sewage treatment works which will hopefully produce less polluting effluent. Both Harare and Chitungwiza should treat storm water discharge. The Harare sewage works have exceeded the capacity resulting in poor effluent quality. The works need to be expanded. In 1993, the city of Harare was sourcing funds to implement expansions to the existing sewage works.

On the positive side, the location of the sewage works is resulting in more than 10% direct recycling of waste water and more indirectly. This proved to be extremely beneficial in recent drought years. The farming activities bring in revenue to the city council.

DISCUSSION

While it may desirable to recycle waste water, it is not without its problems. The waste water must be treated to the extent that it does not cause deterioration in quality of raw water which would make water purification unreasonably expensive. Indeed the quality of treated waste water must be such that the resultant raw water can be effectively rendered potable. This requires that the agencies responsible for water supply should also be responsible for waste water management.

When the two functions are separated, inter-institutional politics make it very difficult, albeit impossible, for the relevant agencies to meaningfully co-operate. Gaborone is a case in point. Water Utilities Corporation is responsible for water supply while the Gaborone City Council is responsible for sewage treatment and disposal. The two agencies function completely independent of each other. While water demand for Gaborone, Lobatse and Ramotswa is about 60×10^3 m^3 day^{-1}, the sewage ponds at Pakalane discharge about 18×10^3 m^3 day^{-1} of effluent. More data on projections on water demand and sewage effluent volumes for the City of Gaborone can be found elsewhere in this volume.

There is not much reuse of waste water apart from a small fraction of effluent from Maruapula sewage ponds which is used to water the golf course greens and a small fraction flowing into the Gaborone game reserve, the bulk of the sewage effluent is discharged to flow into the Notwane river and away from Gaborone. Even if the effluent is not recycled into drinking water sources, there may be possibilities to reuse the effluent to maintain the city's parks and green belts. The effluent cannot definitely be recycled into drinking water sources in its present state as it is of extremely poor quality. Even for use in irrigation of public parks, it may be necessary to change the waste water management from the present oxidation ponds to more effective methods of treatment such as activated sludge and biological filters.

Waste water treatment to produce non-polluting effluent is quite expensive but this may be money well-spent if measured against the cost of alternative water sources when existing sources are lost due to pollution by sewage effluent. The cost of trying to recover "lost" water sources is likely to be much more than that of avoiding pollution of the sources, e.g by adequate waste water treatment. In arid or semi-arid regions, such as southern Africa, there ought therefore to be more efforts put into recycling and reusing treated waste water.

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THE ROLE OF THE MINISTRY OF AGRICULTURE WATER DEVELOPMENT SECTION IN WATER RESOURCES DEVELOPMENT

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ABSTRACT

In Botswana as in other semi-arid areas, both surface and underground water resources are scarce. This makes it necessary to manage these resources in a way that provides optimum usage and at the same time ensures sustainability of supply. It is for this reason that such countries find it necessary to develop Water Master Plans, whose aim is to make projections of water needs and come up with strategies for satisfying the demand for urban, industrial and agricultural water use.

In line with the Botswana National Water Master Plan the Ministry of Agriculture recently revised the Agricultural Water Development Policy. This policy provides guidelines for the development of surface water and groundwater, particularly the construction of agricultural dams and the rehabilitation of open wells for rural agricultural water use. The paper outlines the functions and role of the Water Development Section(WDS) of the Ministry of Agriculture in the development of rural water resources.

INTRODUCTION

The responsibility for providing water is broadly divided as follows. The Department of Water Affairs supplies large villages, and helps District Councils to supply smaller settlements. The Water Development Section develops water resources mainly for agricultural use. This programme, mainly involving dam construction for livestock watering started as far back as 1967.

Due to a high demand for water for agricultural purposes the Ministry of Agriculture strengthened its Water Development Section, through the support of a GoB/UNDP funded project, the **Water Conservation Facilities and Irrigation Development Project BOT/86/010** which started in May 1988 and ended in December 1993. The main purpose of this project was to enable the Section to optimise the use of available sites, to construct larger dams for multipurpose use (for livestock, irrigation, fisheries, etc.), to structurally rehabilitate existing wells and install approved water lifting devices for farmers where these kinds of water sources are viable. Since the programme began, more than 250 earth dams have been constructed and 58 wells have been rehabilitated and drilled, and fitted with well superstructures and pumping units.

THE WATERPOINT DEVELOPMENT PROGRAMME

Through this programme the Water Development Section undertakes to subsidise the construction and rehabilitation of waterpoints, namely, dams and open wells for the purpose of promoting agricultural production. Watering facilities provided for under this programme are for livestock watering or multipurpose agricultural use and not for village water supplies. It therefore follows that these water sources are sited in areas in which there are on-going agricultural activities or where there is a clear potential for promoting them.

In its programme for implementing the policy the Water Development Section undertakes the following activities:

1. **Dam Construction**

It is usually economically more justified to construct a dam for multipurpose use rather than only for livestock watering. Although most of the requests for construction of dams are for livestock watering only, the Water Development Section always explores the possibility of constructing dams for multi-purpose use. The services for the construction of dams are:

a. Available to qualifying groups and for multipurpose dams which are to be managed by the government. Individuals are assisted with technical advice only.

b. Dams whose use include livestock watering are sited at least seven kilometres apart, so as to spread livestock evenly over the grazing. This is meant to avoid convergence of large numbers of livestock around a single watering point, which may cause localised over-grazing.

c. Because dam construction units operate large machines, all dams applied for must exceed storage capacity of 20,000 cubic metres, thereby ensuring cost effective operation.

d. Dams constructed for use by groups are large enough to water 400 livestock units (LSU) for a whole year (more than 6000 m^3). Multipurpose dams will exceed this storage capacity so as to cater for livestock watering and other uses.

e. The Water Development Section provides troughs where required for livestock watering, i.e. at dams built for livestock watering and multipurpose use. This is to prevent pollution of the water by direct watering from the reservoir. In addition, at dams built for multipurpose use, water will be delivered to a point judged to have a good command of the area designated for irrigation.

2. **Dam Rehabilitation**

As soon as a dam is completed, the users are coached on who to maintain and sustain its use. During the first two years after completion of a dam, the Water Development Section closely monitors the dam, to ensure that users comply with the recommended management standards. As more and more dams are constructed, the need for repairs and rehabilitation of older dams is expected to increase. It has therefore become necessary to lay conditions under which a dam may be repaired or rehabilitated. The Water Development Section accepts to repair a dam under the following conditions:

a. If the damage clearly occurred as a result of construction defects, or due to natural calamity, or through normal wear and tear and not as a result of systematic negligence.

b. When it is technically and economically feasible to repair it. For example, de-silting a dam is not always recommended since it is usually an unsound solution both on technical and economic grounds.

c. If the original group is reconstituted, or in the case of a new group, if it is properly registered, to ensure that the dam is maintained and used properly.

3. **Well Development**

The Water Development Section is involved in the rehabilitation of traditional open wells. These are usually completed with well superstructures and fitted with suitable type of handpumps. Almost all of the well development works are carried out in minor settlements such as lands areas and cattle posts. These services are rendered to both groups and individuals albeit with slightly varied conditions for individuals. The Water Development Section has also constructed sand river abstraction wells in some few places such as along the Tati, Motloutse and Shashe rivers. This encourages local farmers to utilise appropriate technology to obtain and use groundwater.

According to the National Water Master Plan (BNWMP 1991), seventy(70) percent of cattle
water requirements come from groundwater sources and in drought periods this may approach one hundred (100) percent. Groundwater is indeed an important resource for minor
settlements, and fairly cost effective. The recent study on 'The Impact of Small Dams on down stream water resources' has shown that some catchments, in particular the Gaborone and the Bokaa dam catchments are close to being over-exploited. In this case there will be greater reliance on groundwater for cattle watering in these catchments in the near future.

CONCLUSION

As Botswana is not endowed with abundant water resources it is necessary to plan and develop water resources which are cost-effective and sustainable, as well as ensure sustainable use of related resources eg. grazing land. This requires an approach based on the use of appropriate technology and the involvement of the community in planning and implementation of projects.

In addition to the construction of dams and hand dug wells the Water Development Section will in future need include the construction of other types of water sources, such as haffirs, more sand river extraction developments, rain water harvesting systems, and artificial groundwater recharge schemes etc. The on-going Lands Area Water Supply Study (LAWSS 1991) is expected to come up with proposals and technologies for water supply development in scattered rural areas.

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SOME HYDROLOGICAL CHARACTERISTICS AND DESIGN CRITERIA FOR CONSTRUCTION OF SMALL DAMS IN BOTSWANA

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ABSTRACT

The present paper describes the procedures and methods of estimating hydrological parameters such as design floods of different return periods, mean annual runoff and reliable yields of the reservoirs for the design of small dams in Botswana, where most of the dam sites are ungauged. The methods used range from simplified equations and relationships derived through detailed analyses of the existing hydrological and meteorological data both in Botswana and neighbouring countries, to complex use of Pitman model. The paper also gives a dam classification and design criteria presently used by the Water Development Section of the Ministry of Agriculture.

INTRODUCTION

The Water Development Section (WDS) of the Ministry of Agriculture has been constructing small dams in Botswana since 1966. Until 1988, the methods of estimating runoff, safe yield and design flood were too general and did not take into account the available hydrometeorological and river flow data.

Under the Water Conservation Facilities and Irrigation Development Project (BOT/86/010) which started in 1988, an international consultant (M.R. Hasan) was first engaged to undertake study on rainfall/runoff relationship, river floods and safe yields of the reservoir for small ungauged dam sites. A report "Guidelines on Hydrology of Small Dams" was produced. A second consultancy service (A. Bullock) was again engaged in 1993 to upgrade the first "guidelines" in the light of the accrued hydrological data during the last four years. By that time, a report "A study on the Impact of Small Dam Construction on Downstream Water Resources" had been prepared by Sir Alexander Gibb & Partners (Botswana) for the Department of Water Affairs. Finally, the new report "Hydrological Procedures for the Design of Small Dams in Botswana" was released.

The present paper is the brief presentation of that report, which is mainly used by the WDS for the design of small dams throughout Botswana.

DESIGN FLOODS

The guidelines are appropriate and recommended for catchments in Eastern Botswana ranging from 10 to in excess of 1,000 km^2. The Botswana recommendations are based on estimation of flood peaks of return period. Two methods are used for estimation of design flood; first, the Flood Studies Report (NERC, 1975) Regional Approach and second the Regional Maximum Flood approach (Kovacs, 1988).

- **The Flood Studies Report Regional Approach**

The Flood Studies Report regional approach is based on estimation of the mean annual flood (MAF) from catchment characteristics and a regional flood frequency curve. The catchment characteristic equation has been developed using data from 46 catchments in Botswana, Zimbabwe, Namibia and South Africa with catchment area of less than 1,000 km^2.

The objective of the approach is to enable information from a region to be used to relate Q(T), the flood having return period T, to an index flood, the mean annual flood (MAF), being the arithmetic mean of the annual maximum flood series (Table 1).

Table 1. Some meteorological and hydrological data of Botswana

Station	No. of years	Eff.Area	MAP	PE	MAF	C.V.	Qmax
Metsomotlhaba	11	3570	460	2000	47.3	120.9	202.0
Metsomotlhaba	8	1320	490	2000	65.8	78.3	183.5
Kolobeng	13	166	490	2000	17.8	111.0	56.3
Bonwapitse	7	-	-	1975	18.3	53.5	35.1
Tantswe	6	-	-	1975	63.0	106.5	190.1
Mahalapswe	19	754	456	1975	101.3	93.6	313.2
Lotsane	10	6395	479	1975	28.6	43.1	44.5
Motloutse	14	5960	383	2050	317.5	77.6	934.1
Motloutse	3	-	-	2050	759.8	67.1	1335.1
Motloutse	3	-	-	2050	250.0	46.4	350.0
Shashe	21	4160	490	2050	545.2	115.3	2699.2
Shashe	21	2460	509	2050	255.7	116.6	1364.7
Ntshe	18	800	533	2050	224.2	218.5	2154.8
Tati	19	570	530	2050	309.8	175.8	1973.5
Letlhakane	3	-	-	2050	164.4	13.7	187.1

Eff. Area = Effective catchment area in km2
MAP = Mean annual rainfall in mm
PE = Mean annual evaporation in mm
MAF = Mean annual flood in m3/s
C.V. = Coefficient of variation of series of annual maxima in %
Qmax = Maximum observed flood in m3/s

At the gauged sites MAF can itself be estimated either directly from a short period of record or indirectly by interpolation. At an ungauged site, it is often necessary to derive an estimate of MAF from a regional study. Out of twelve methods of estimating MAF from catchment characteristics potentially appropriate for Botswana, the following method is recommended.

$MAF = 0.114\ Area^{0.52}\ MAP^{0.537}\ (m^3/s)$

$Area$ = Catchment area (km^2)

MAP = Main annual rainfall (mm)

The equation has a factorial standard error of 2.04, that is 68% of estimates will be within 2 and 0.5 of "true" MAF.

Concerning the Regional Flood Frequency Curve, the Botswana/South Africa curve from Farquharson et. al (1992) is recommended as most suitable for Botswana (Figure 1) with mean annual rainfall less than 600 mm. To obtain the flood of a given return period, Q(T), the MAF should be multiplied by a factor, from the following table or from Fig.1.

Return period	20	50	100	200	500	1000	2000
Q(T)/MAF	2.99	4.70	6.51	8.92	13.4	18.1	24.5

Example:

$$\begin{aligned} Area &= 30.5\ km^2 \\ MAP &= 505\ mm \\ MAF &= 0.114\ Area^{0.52}\ MAP^{0.537} \\ &= 19.1\ m^3/s \end{aligned}$$

Multiplication factor for 100 year return period is 6.51.

$$\begin{aligned} Q(100) &= 6.51 \times 19.1 \\ &= 124.34\ m^3/s \end{aligned}$$

- Regional Maximum Flood Approach

The Regional Maximum Flood approach is based on a method developed in South Africa, which extended into Botswana and other adjacent countries. Maximum flood peaks recorded since 1856 at more than 500 sites in Southern Africa (principally within South Africa) have been used.

The regional maximum flood (RMF) is an empirically established upper limit of flood peaks that can be readily expected at a given site. Out of eight maximum flood regions delimited, five fall in Botswana (Figure 2).

In this method, the RMF can be instantly calculated if the geographic position of the site and its effective catchment area are known, for any catchment varying in size from 1 km^2 to in excess of 100,000 km^2. The RMF compares favourably with results obtained by other methods. Flood peaks in the 50 to 200 year recurrence interval can also be estimated from RMF, which is the basic requirement in dam design.

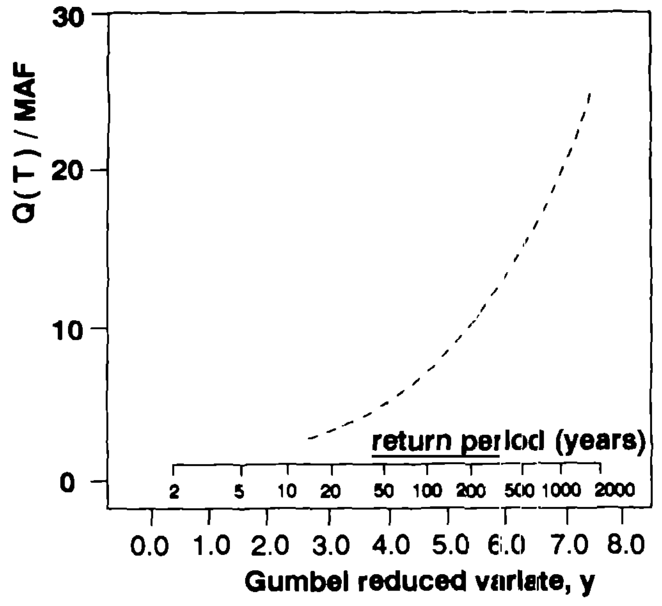

Fig. 1 Regional Flood Frequency Curve for Botswana (Source : Farquharson et al., 1992).

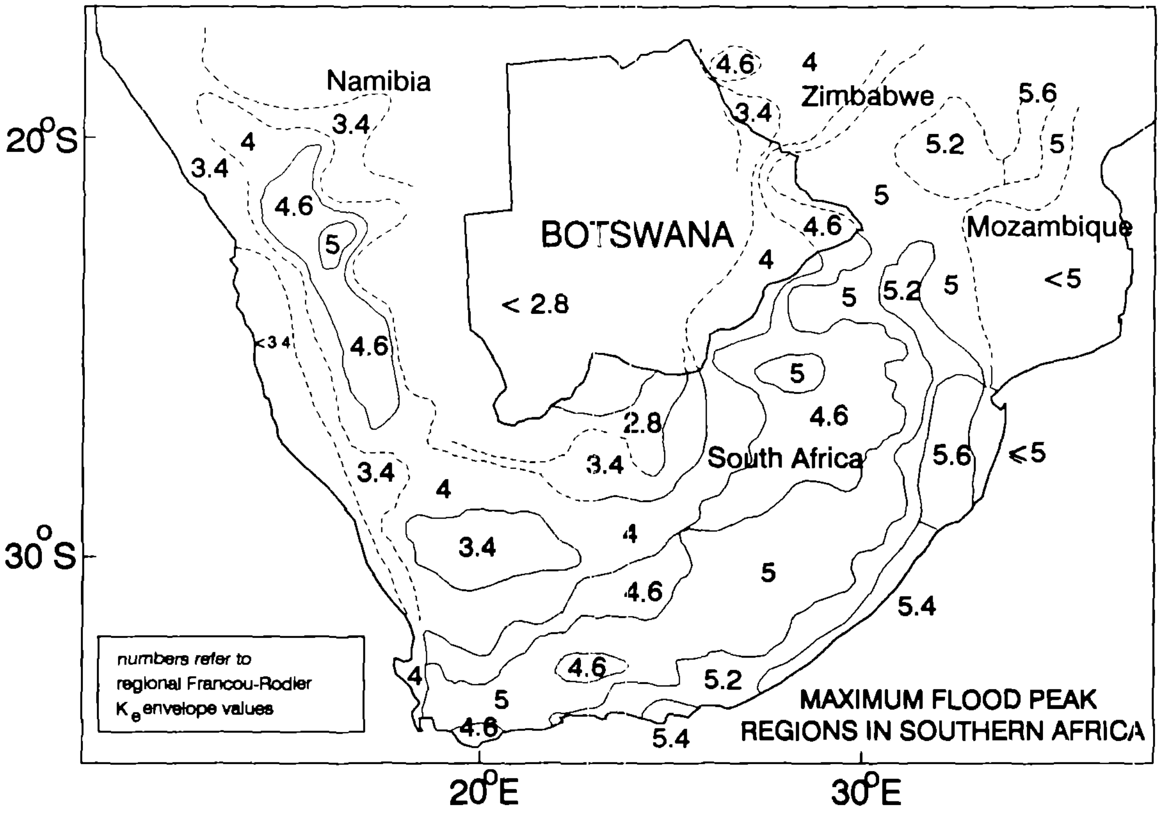

Fig. 2 Delineation of RMF regions in Southern Africa (Source : Kovacs, 1988).

Three steps are involved in the estimation of the design flood:

Step 1; Identify the Maximum Flood Region in which the proposed site is located.
Step 2; Estimate the Regional Maximum Flood by application of the appropriate equation from Table 2.
Step 3; Estimate the flood of return period of interest by application of appropriate multiplier from Table 3.

Table 2. RMF Equations in Botswana

	TRANSITION ZONE		FLOOD ZONE	
Region	RMF m^3/s	Areal Range km^2	RMF m^3/s	Areal Range km^2
2,8	$30A_e^{0.262}$	1 - 500	$1.74A_e^{0.72}$	500 - 500,000
3,4	$50A_e^{0.265}$	1 - 300	$5.25A_e^{0.66}$	300 - 500,000
4	$70A_e^{0.34}$	1 - 300	$15.9A_e^{0.60}$	300 - 300,000
4,6	$100A_e^{0.38}$	1 - 100	$47.9\ _e^{0.54}$	100 - 100,000
5	$100A_e^{0.50}$	1 - 100	$100A\ _e^{0.50}$	100 - 100,000

Table 3. Multipliers for Floods of Different Return Periods

SOUTH AFRICA, LESOTHO AND SWAZILAND			Effective catchment area A_e (km^2)		
Region	T	<10	30	100	300
5	50	0.447	0.416	0.380	0.411
	100	0.550	0.521	0.488	0.517
	200	0.661	0.636	0.608	0.633
4,6	50	0.416	0.385	0.350	0.381
	100	0.524	0.495	0.462	0.491
	200	0.629	0.603	0.576	0.602
4	50	0.426	0.426	0.426	0.390
	100	0.562	0.562	0.562	0.529
	200	0.692	0.692	0.692	0.665
3,4	50	0.317	0.317	0.317	0.281
	100	0.428	0.428	0.428	0.391
	200	0.570	0.570	0.570	0.536
2,8	50	0.317	0.317	0.317	0.281
	100	0.428	0.428	0.428	0.391
	200	0.570	0.570	0.570	0.536

Namibia and Zimbabwe

Region	T	Effective catchment area A_e (km^2) <10	30	100	300
5	50	0.447	0.416	0.380	0.411
(Zim)	100	0.550	0.521	0.488	0.517
	200	0.661	0.636	0.608	0.633
4,6	50	0.589	0.561	0.530	0.558
	100	0.741	0.721	0.699	0.719
	200	0.871	0.860	0.848	0.860
4	50	0.562	0.562	0.562	0.529
	100	0.676	0.676	0.676	0.648
	200	0.767	0.767	0.767	0.746
3,4	50	0.550	0.550	0.550	0.517
	100	0.639	0.639	0.639	0.610
	200	0.733	0.733	0.733	0.711

MEAN ANNUAL RUNOFF (MAR)

The other most important data for dam design is estimation of the mean annual runoff (MAR). There are three alternative methods for estimation of MAR; transfer of gauged data, regional rainfall/runoff curve and application of the Pitman monthly rainfall/runoff model.

Considering the fact that most small dam catchments are ungauged, it is regarded that the rainfall/runoff curves (Figure 3) should be used to estimate the MAR, where in many cases the reservoir volumes are less than the MAR. Two separate curves are presented for the Northern region (upper curve) and the Southern region (lower curve). The curves were derived from data from 12 records in Botswana, 9 records in Zimbabwe and 4 records in South Africa. To complement the observed data, mean annual runoff values were derived from Pitman rainfall/runoff modelling with varying values of mean annual rainfall. The modelling results were used to define smooth curves through the scattered data.

For multipurpose dams (both irrigation and cattle watering), where water releases should strictly meet the irrigation demands, the Pitman model should be used using whatever data available (data from nearby rainfall stations and river gauges).

STORAGE/YIELD RELATIONSHIP

Two methods are being used for estimation of storage/yield relationships.

The first method is based on Gibbs (1992) which uses an "average" Botswana storage/yield curve of 95% reliability (Figure 4), based on six of the storage/yield curves, estimated by Gibbs (1977) by using the combination of Pitman (1973) and Midgley and Pitman (1969) techniques with topographic survey information for the sites.

The second method is based on the Hydrological Research Unit (1981) which can be extrapolated from South Africa into Botswana. The method can incorporate surveyed volume/area relationships of the reservoir and will estimate the reservoir storage required to supply yields with different reliabilities. The detailed procedure of this method is not given in this paper.

DAM DESIGN CRITERIA

Until now there are no approved dam size and hazard classifications and design flood requirements for design of small dams in Botswana. Gibbs (1992) recommended the dam classifications and design floods in the report "A Study of the Impact of Small Dam Construction on Downstream Water Resources", and they are given in Table 4.

SEDIMENTATION OF RESERVOIRS

Sedimentation rates vary considerably for the five dams studied in Botswana from as low as 8 $t/km^2/yr$ to 240 $t/km^2/yr$. Due to complexity of the process of sedimentation in reservoirs, a 15% of the reservoir volume is adopted, in most cases, as the dead storage volume. This value is adjusted based on basin characteristics of particular dam site.

IMPROVEMENT OF THE EXISTING METHODS AND AVAILABLE REFERENCES FOR DAM DESIGN

All equations and relationships being used to estimate the hydrological data for dam design, which have been presented earlier are based on limited available data. At present the Water Development Section is carrying out activities to complement the existing data in the following aspects:

1. Rainfall/runoff relationships by recording the reservoir filling process;

2. Sedimentation rate by carrying out reservoir area surveys during drought years when most of the reservoirs are empty and;

3. Flood discharge estimates from maximum reservoir water levels and river stage levels downstream.

When more data will be available in the aspects mentioned above, the existing procedures and methods will be revised accordingly.

Table 4. Proposed Dam Size Classification

Size	Reservoir Capacity (10^3 m^3)	Height (m)
Very small	Below 50	Below 5
Small	50 - 1,000	5 - 8
Medium	1,000 - 5,000	8 - 15
Large	5,000 - 20,000	15 - 30
Major	> 20,000	> 30

Hazard Potential Classification

Hazard Potential	Loss of Life	Economic Loss
Very low	Extremely low	Minimal
Low	Improbable	Marginal
Moderate	Possible	Appreciable
High	Probable	Excessive

Hazard Classification

Size	Hazard Potential			
	Very Low	Low	Moderate	High
Very small	Not normally a safety risk, class to be determined depending on circumstances			
Small	4	3	2	1
Medium	3	3	2	1
Large	2	2	1	1
Major	1	1	1	1

Design and Flood Peak Return Periods

Hazard Class	Design Flood	Peak Flood
1	1,000 year	2,000 year to PMF, depending on risk to life
2	500 year	1,000 year
3	200 year	500 year
4	100 year	200 year

Non-safety risk dams : to be assessed according to circumstances if deemed a safety risk, otherwise based on economic considerations only.

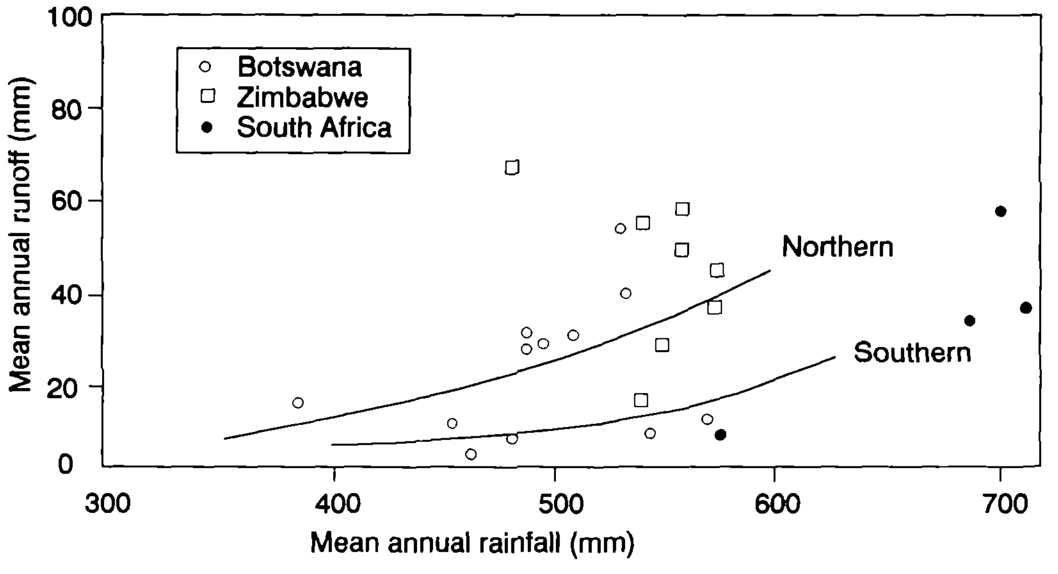

Fig. 3 Mean annual rainfall and runoff curves for Botswana (Source: Gibbs, 1992).

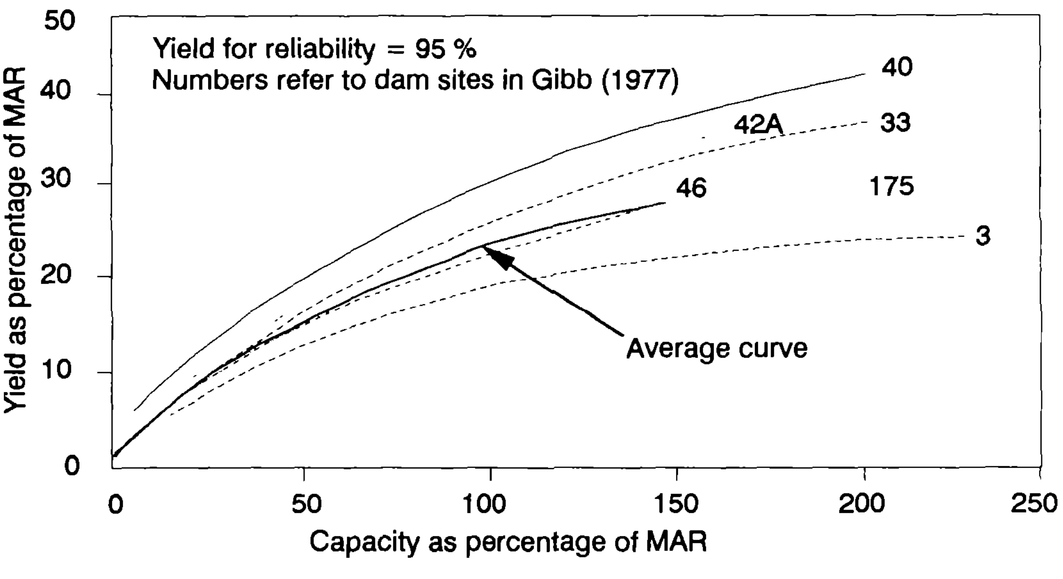

Fig. 4 Gibbs (1992) 'average' storage/yield curve and original storage yield curves for six proposed dam sites.

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COMMUNITY PARTICPATION IN RURAL VILLAGE WATER SUPPLY IN BOTSWANA

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ABSTRACT

Formalised Rural Water Supply in Botswana has a short 20 year history. Since 1972 more than 450 villages have been equipped with reticulated supplies. Large amounts of international development assistance and domestic development funds have been used to achieve this rapid modernisation of rural village water supplies.

The major international donors have since phased out much of their support to the water sector. Botswana now relies mainly on internal resources and domestic development funds to maintain rural village water supplies. The investment in these supplies is substantial and considerable funding must be continued to protect this investment. In the light of the short history of rural village water supply this paper questions the sustainability of some current policies and practices.

Currently the resources of District Council Water and Wastewater Departments are minimal. However, District Councils may in the near future be resourced to take on substantial development works in addition to their regular operation and maintenance duties. The need to change the system of development, and promote efficiency and sustainability, are well recognised.

Community participation was traditionally the means of providing water to villages in Botswana. Water development practices over the past two decades have done little to maintain popular interest and will to participate in community development. Due to the lack of community interest today many village water supplies are poorly managed, appliances are abused and maintenance costs are unnecessarily high. Community participation needs to be resurrected to support all further village water supply developments.

Community spirit still exists in the rural villages of Botswana. This communal spirit ought to be encouraged and accommodated by policies in the water sector. Standpipe user groups can be formed under the auspices of existing village institutions. These groups can input labour and ideas into their own development. More economical development, increased community awareness and reduced maintenance obligations for District Councils are the aims of the proposed system changes. The current transitional period in the water sector in Botswana must be used to promote community participation with the objective of sustaining rural village water supplies.

A preliminary framework that allows for the integration of community participation within the formalised water sector is proposed. In conclusion District Councils should be encouraged to integrate community participation into all future water developments and promote community interest in existing village facilities.

INTRODUCTION

This paper has been written primarily as a discussion paper with the goal of inspiring those currently working with rural village water supplies in Botswana. Based on recent experience in the Okavango Sub-District of Botswana's North West this paper aims to shine a little light of optimism on the topic of community participation in rural village water supply development.

The past few decades of development theories and practices have focused largely on the "modernisation" aspects of development. Urbanisation and rapid industrialisation have been the hallmarks of such development and it is only in recent years that these policies have been criticised for their failure to call into play the human factor - people participation. We in Botswana are now faced with the problem of maintaining a system of rural village water supply schemes that have been installed, or rather bequeathed to Botswana, with a minimal amount of community involvement.

This paper asserts that it is now the time to instigate a revival of community participation in all aspects of rural village water supply development. The Water and Wastewater Department of the Okavango Sub-District knows it can be done. The necessary enthusiasm has been seeded and it is time that the framework to facilitate development projects with people participation was formalised by all concerned parties in support.

BACKGROUND

The history of centrally planned Rural Water Supply in Botswana begins only two decades ago in 1972 when the first Village Water Supply Programme (VWSP) was launched. Before this villages had only very limited services and the original goal of the VWSP was to equip all villages with populations in excess of 500 with a reticulated supply. Villages were prioritised according to their population size. By 1978, 50 villages had been served, 100 by 1980 and 290 by 1989. Today the figure exceeds 450 and it is planned to bring this total near to 500 by the year 2000 (BNWMP, 1991).

In order to achieve such a phenomenal burst of activity in the water sector large amounts of international development assistance were required, both for funding and for technical support. The Swedish International Development Agency (SIDA) was originally the main external support agency for the programme. UK, Dutch and German agencies have also been involved as has the Lutheran World Federation, BCC, US Peace Corps and UNDP. Unfortunately it appears that in many cases the focus was on rapid development and not on "sustainable development".

THE CURRENT SITUATION

"The Major Donors are now progressively phasing out their support to the water sector, and it is reasonable to assume (and indeed expect) that by [the year] 2000 Botswana will have to rely on its own resources to maintain the ongoing considerable investment in rural water supplies" (Botswana Society, 1992).

The decline in international support is due partly to worsening economic conditions in the donor countries but also because many donors now feel that Botswana can manage and fund its own development. By 1991 Botswana was funding 100 % of its water sector recurrent budget, and 90 % of its capital development budget from domestic, rather than international, development funds.

Currently the resources of Water and Wastewater Departments are stretched to the limit with routine operations and maintenance and there is little chance to tackle progressive development works. There are however plans afoot to further resource District Councils to enable them to perform more construction and substantial upgrading - taking over a large proportion of development works which are currently undertaken by the Department of Water Affairs (DWA) and private contractors.

THE MOVE TOWARDS SUSTAINABILITY

Sustainability is the pronounced goal of development in Botswana today. As the rate of rapid development slows down we are still faced with maintaining and sustaining the performance of, the development that has already been achieved. Even if no additional development works were to be attempted in the village water supply sector the water sector could remain busy with upgrading alone. As villages are typically designed with a design horizon of 10 years some 50 villages per year will still require rehabilitation. "Since inception of the VWSP in 1972, the average implementation rate has only been 20 - 25 villages per year, and this was with major donor support in terms of manpower and finance" (Botswana Society, 1992). It is generally recognised that there is no excuse for complacency.

The question then remains; How can Botswana efficiently sustain the development it has already achieved in the village water supply sector with an ever decreasing degree of foreign financial and technical support?

THE SEARCH FOR AN ANSWER

Given the present capabilities of some District Council Water Departments the time when the desired level of decentralisation can be achieved appears to be far away. Nevertheless the move is progressing, even though it is still in its infancy. Numerous studies have also been performed to assess this situation and many recommendations made for improvements in the rural village water supply sector.

The Botswana National Water Master Plan Study (BNWMP, 1991) briefly examined some of the strengths and weaknesses of the present situation in Botswana with respect to establishing sustainability in rural village water supplies. The current status of community institutions were summarised as follows :

Strengths

Well established local institutions. (Kgotla, headman, Village Development Committee etc.)

Traditional structures conversant with management of local level affairs

Locally elected councillors / MPs able to influence Government and District Council administrative decisions

Weaknesses

Lack of genuine community involvement in decision making and setting priorities

Extensive central control over local management (institutional and financial)

No community commitment required towards construction or future O & M, hence community choice illusory

It is doubtful, however, that the latter two of the "strengths" as listed above can always be counted upon as positive aspects of the present institutions. Much development today is beyond the scope of management of local level affairs that the "traditional structures" were once conversant with. The ability of locally elected councillors and MPs to influence Government and District Council administrative decisions is also as much of a weakness as a strength depending on the degree of genuine community will that the official chooses to represent.

"Reviewing the 'weaknesses'...it is obvious that many of these can be rectified without major structural changes in the rural water sector. Indeed most of these weaknesses are well recognised by the Government...[and] can be rephrased and converted to remedial actions..." (BNWMP, 1991).

The one 'remedial action item' that this paper concentrates on reads :

> "Prepare a standpipe upgrading programme with design options, implementation plans and budgets with the aim of establishing hygienic conditions at the waterpoints, preferably with the assistance of the actual users.

IS COMMUNITY PARTICIPATION OUT OF CONTEXT ?

Efforts to attain a level of cost recovery from public standpipes have been attempted previously in Botswana. "Charges for the use of standpipes were introduced, found to be unpopular and difficult to collect, and abandoned in 1978" (BNWMP, 1991). This approach to cost recovery would still meet with much resistance in Botswana and would not be in line with Government policy. Moreover such measures usually tend only to compromise the welfare of the poorest members of a community which would in fact increase the load on other Government institutions such as hospitals and clinics.

However, historically in Botswana the concept of "free" water has not existed without a significant element of community participation. "Traditionally, water was free in the sense that people were not charged a fee for it. But they were often required to contribute labour, cattle, or cash to the development [and maintenance] of the water source itself. For example, chiefs and headmen would make the members of certain age groups (*mephato*) responsible for helping in the construction of a new borehole and its associated reservoir, trough, fencing etc.. Public participation was also required in the continued maintenance of the water point, and ensuring discipline in its use."

So the answer to the question is a resounding "No". Community participation has traditionally been an integral part of village life in Botswana since long before the inception of the Village Water Supply Programme. We should perhaps now ask another question. What went wrong? Why has the element of community spirit been allowed to wither in the short twenty year history of the VWSP? Indeed the achievements of the programme have been impressive with more than 450 village supplies up and running since 1972. What is far from impressive, however, is the minimal amount of community respect for the schemes that were bestowed upon them during these two decades of modernisation.

Operations and maintenance obligations of District Councils now include many of the tasks that would have been carried out by community members, or possibly not required at all, if some of the traditional system had been integrated into the VWSP. As it is, District Councils often cannot maintain a sufficient level of service to many of their water points, criteria for supply are not always met, and community welfare is reduced as a result. Village Water Supply Operators (VWSO) are employed by District Councils to operate and maintain village pumping and reticulation equipment but, admittedly, fulfilling their duties in many of the larger villages is a daunting task without community support. In short what is required is a reintroduction of the values of the past. Today's technology can function within the framework of a community based structure. The concept of community decision and action in itself is still an integral part of society in Botswana and must be respected and exercised as such.

THE OKAVANGO EXPERIENCE

The District Council Point of View

Currently it is the Department of Water Affairs (DWA) who are responsible for the design and implementation of new and upgraded village water supply schemes. However, it appears to be the intention of MLGLH to have District Council Water and Wastewater Departments take over some of the duties of DWA in the near future. "District Councils are gradually undertaking minor extensions to village supplies throughout the country and it is anticipated that this trend will increase over the remainder of this decade and beyond." This is indeed the case in the Okavango Sub-District where NWDC has recently received Capital Development Funds specifically for the purpose of expanding reticulation and bringing facilities in line with current design criteria in several rural villages.

With respect to maintaining standards one of the major shortfalls, in the Okavango Sub-District at least, is the existing conditions of standpipes and handpump water sources. Very few currently appear to meet design standards, as far as fencing and drainage go. However, fortunately a recent survey by DWA found the bacteriological water quality to be acceptable in all but a few cases. NWDC certainly have plans to bring all water points to an acceptable standard but currently resources dictate that regular operations and maintenance duties will take priority and little upgrading of existing water points will be possible.

A problem experienced by NWDC is that there appears to be little respect of water points by users. Over the last 20 years new water supply schemes and upgrades have arrived "out of the blue" with little or no involvement of community members. In essence, rural village populations have been given water without attaining an appreciation of its worth. Water is consequently devalued and village populations have become dependent on the Council in every aspect of source maintenance.

The purest expression of lack of community interest can be observed with the relationship between Council employed Village Water Supply Operators (VWSOs) and members of the community. Standpipe users fail to take action to help themselves, for example, if a standpipe needs attention, because they know that the VWSO is paid to attend to such matters. At the same time community members will not complain if the VWSO fails to perform his duties as he is in fact a member of their own community. This self defeating inability to improve water supply operations at the community level is promoted by the current job definition of the VWSOs.

Efforts by NWDC to revalue water

Considerable effort has been made by NWDC Water and Wastewater Department staff over the past year to promote community appreciation of rural village water supplies. Kgotla meetings have been attended to explain the capabilities of NWDC in relation to the aspirations of villagers. Two villages VDC's have recently made an impressive effort to fence and protect standpipes but this appears to have only happened as drought relief funds were available. In reality it is still the case that villagers ask for the Council to come and construct additional standpipes with little enthusiasm for community input.

However, a recent experience in Gumare village has given renewed optimism to NWDC staff with the completion of the first standpipe with (unpaid) community participation. The initial kgotla meeting was held in February 1993 to inform villagers that NWDC would give priority to constructing stand-pipe extensions in areas of the village that demonstrated a will for community input. Eight months later word reached the Water and Wastewater Department that community members were "ready to dig". A few days later water was flowing in this neighbourhood.

Following this successful activity people from other parts of the village have expressed interest in organising their local community for similar exercises. A poster was designed to promote this approach but it appears that word of mouth is a sufficient means of communicating to the community now that one successful project has seeded the will for participation in other neighbourhoods of Gumare village.

The implications of the community participation approach

Depending on the complexity of projects and the need for skilled labour it is debatable whether savings on capital costs can be achieved with the use of free community labour. Trench digging for pipe laying, however, is an example of an activity that may demonstrate substantial savings with the simple application of such labour. More importantly, especially to an institution such as a District Council, it is the sense of understanding and value installed in the participants that is the goal of projects approached in this manner. Village standpipes have a much better chance of being respected by community members if the users themselves have had a part in its construction. The maintenance implications are tremendous.

The whole philosophical debate on value gets rather theoretical, complex and is in itself becomes non-conclusive but this paper maintains that any form of community participation in development will generally serve to raise the consciousness of the community involved and benefit the village as an entirety. The framework postulated below calls for direct community involvement in assessment of needs and planning for development. This process requires the active conscious involvement of village members and would give many of the community experience with formalised institutions.

A PROPOSED FRAMEWORK FOR COMMUNITY PARTICIPATION

In order to achieve a system by which community participation can be effectively utilised a framework must be clearly established to facilitate communication and cooperation

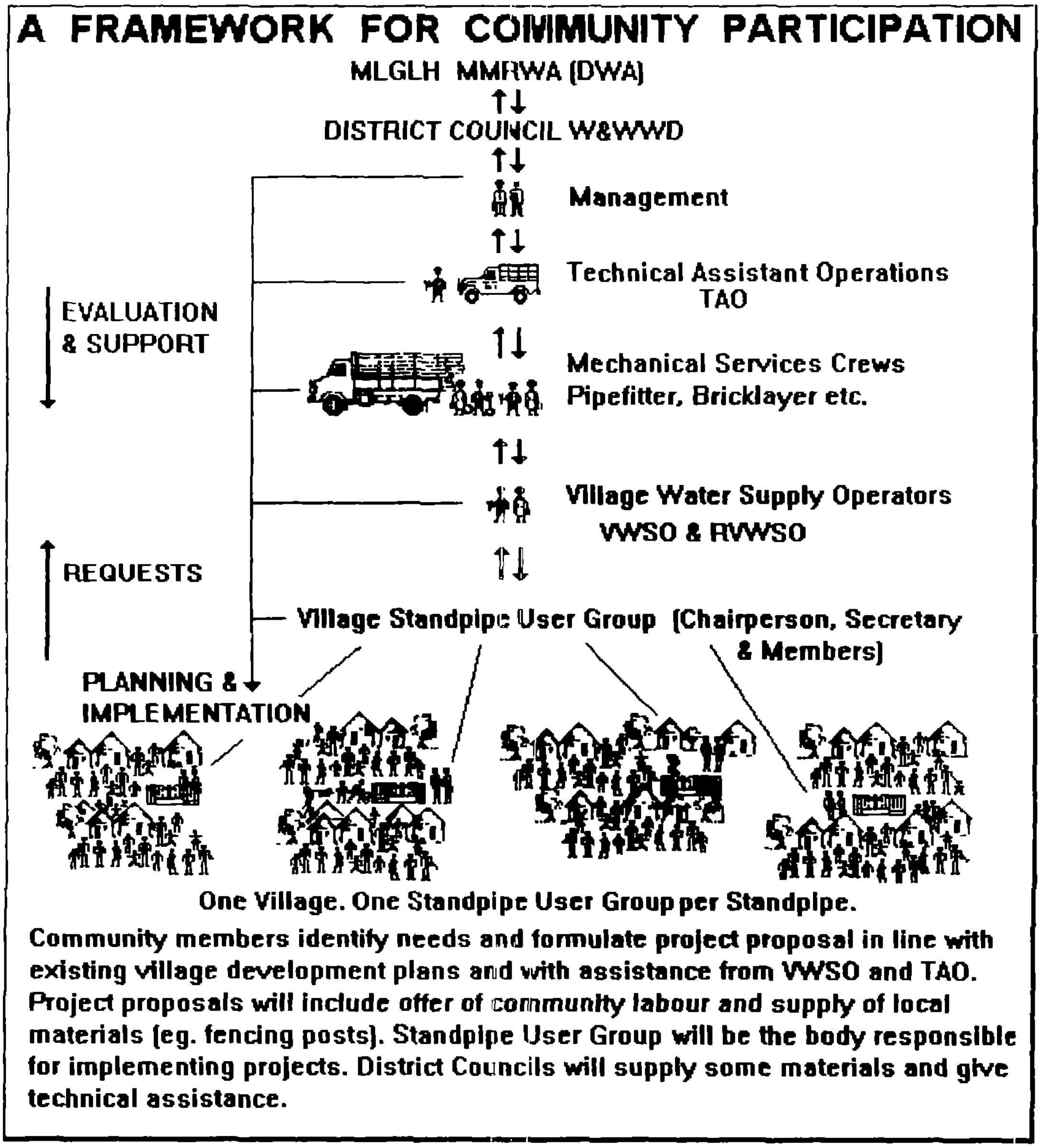

Fig. 1 A framework for community participation.

between interested parties. The diagram below depicts a framework which is proposed as a starting point for discussion. Note that this framework is based upon the accepted Human Resource Development (HRD) plan for Water and Wastewater Departments with the simple addition of standpipe committees. These proposed committees would however not be a paid component of Water and Wastewater Department establishment so a framework formulated along these lines would not alter the official establishment or require additional wages.

In fact, as one radical (for Botswana) alternative it could be proposed that District Councils require that the wages for VWSO and RVWSO be paid for entirely by the communities themselves. This would improve community interest in the performance of the VWSO and certainly promote his or her responsiveness. This possible approach implies that District Council funding for wages could be limited to Mechanical Services crews. This paper, however, suggests that it is perhaps more appropiate for the time being to maintain funding and training of VWSOs through District Councils. All activities at the village level would therefore require the contribution of, if not direct funding, then at least effort in the form of labour, from the community.

An important aspect of such a framework is the channel of communication and support. In order for standpipe user groups to make reasonable requests they must be informed of plans to extend reticulation (with their support) and expected standards of standpipe construction. Requests and harvesting of benefits must be a two way process. Without good communication and support there is a fair chance that community enthusiasm will be built up with false hopes and that District Councils may not be able to deliver the expected materials and skills. Embarking on such community participation projects without serious intention of following up projects, or without the means of support, would create a sense of disillusionment within the community. This would make efforts to inspire community participation even harder in the future.

District Councils will be required to do some preliminary work in mapping and defining areas of standpipe use. All community members using a standpipe would become members of the standpipe user group. It is envisaged that the standpipe user group representatives, perhaps a chairperson and secretary, could be elected from the neighbourhood under the auspices of the VDC. The two elected representatives of the standpipe user group would then be responsible for communicating with district councils and for organising local labour and maintenance. No money would be paid to the representatives but the experience itself should be valued and promoted as such.

Further development of the framework is required with studies of well documented case studies from actual projects undertaken using community participation.

CONCLUSION

We have two options if we wish to maintain the current practice of endeavouring to provide potable water to community standpipe users. The first option requires substantial funding to be found and continued in order to equip District Councils with standpipe maintenance and construction crews on an active programme of standpipe reconstruction and protection and VWSO support. The second option, and the only one that this paper asserts as viable in the economic, social and cultural setting, is to reintroduce the requirement for community participation into all rural village water supply schemes. This would not require any major changes at existing institutional levels. Nor would it require major additional funding. It does however require the understanding and support of all institutions from ministerial, through district council to Village Development Committee and community level.

What does, however, require a major change is the manner in which village water supply schemes are planned and implemented. Fortunately, in any case, we are witnessing the beginning of a transitional period in the water sector in Botswana. As District Councils are resourced and embark upon their own rehabilitation projects, in whatever form, they are in a good position to resurrect community spirit. All new developments must be based on community participation.

Recent experiences in the Okavango Sub-District indicate that the spirit is still there and just waiting to be reintroduced to community development projects. Reports and documents reviewed for this paper, and indeed discussions with people active in the water sector, suggest that this community participation should be a part of future water supply development. "In the longer term, consideration should be given to reviewing active community participation in the development of rural water supplies, to enhance the O & M control of the supplies and to provide a safeguard in the event of any unforeseen [or the inevitable] reduction in Central Government support to District Councils recurrent budgets" (Botswana Society, 1992).

This paper concludes that District Councils should all endeavour to integrate community participation into development projects but that the process should be consistent and openly demonstrate to the communities a reward for their efforts. We therefore invite discussion on this topic with the aim of restoring participation in the communities within a framework that will ensure its support and sustainability well into the future. The framework, therefore, also relies on competent management abilities and sound technical skills from the staff formally employed in the water sector. Community participation is not a substitute for effective development of human resources - but it could prove to be a valuable complement.

The Water and Wastewater Department of the Okavango Sub-District will continue their endeavours to promote development by participatory techniques as resources permit. The topic of standpipe user groups has been preliminarily discussed with some community members and efforts to finalise the formation of twenty such committees will be attempted in Gumare (and possibly other villages) in 1994 if Government support (morally) and community spirit remains conducive to such an approach.

ACKNOWLEDGMENTS

The Okavango Sub-District Water and Wastewater Department gratefully acknowledges all those involved in the "great dig way down just off that part of the village to the North of Tubu Road way" for their impressive digging efforts of August 1993. Community spirit unleashed - the great human digging "machine" on that inspirational weekend.

KEITUMETSE THATA BATHO BABA NTLE.

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SOLAR DESALINATION OF WATER FOR REMOTE, RURAL COMMUNITIES IN BOTSWANA: A NEW APPROACH

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ABSTRACT

The paper describes a new type of thermal-electrical solar still for the production of drinking water for remote rural communities. The design is based on a conventional basin type solar still and is modified to include a low-power exhaust fan. The fan pumps out the water vapour produced in the still and passes them through a condenser coil where the latent heat of condensation is recycled to pre-heat saline water for recharge of the still. This improves the thermal efficiency of the still by a factor of 2.5. The overall energy efficiency of the still is estimated to be 1.25 times the overall efficiency of a conventional still. The new still holds potential for providing drinking water to the remote rural settlements in Botswana.

Although over two third of the earth's surface is covered with water in the form of oceans, seas, lakes, rivers and ice and snow, a large population of the world faces a serious drinking water shortage. The causes of this shortage, which vary from country to country are chronic and frequent drought, scarcity of surface water in the form of lakes and rivers, pollution of lakes and rivers, poor quality of ground water, economic restraints for some countries to install water purification and treatment plants etc. For the developing countries the water-problem is compounded with break-out of diseases, failure of crops, inability to attain self sufficiency in food, poor health standards and malnutrition of its masses.

DRINKING-WATER PROBLEM IN BOTSWANA

Botswana in the Southern African region has a unique drinking-water problem. It is a land locked country lying between latitude 17° S and 27° S and longitude 20° E and 30° E. The country faces long and frequent droughts. There are no lakes and perennial rivers within the country except for the Okavango Delta in the north-west and Chobe River system. With a total population of 1.35 million and area of 581,730 km^2, the country is thinly populated. About 74% of the population is rural of which a large number live in remote rural settlements of few hundred to just over one thousand. Nearly 70% of the country is covered with the sands of the Kgalagadi desert. Ground water is found at depths of 80 m or more and mostly the water from the bore holes is highly saline, unsuited even for watering of cattle, agriculture or construction. If potable water is struck, the yield is generally inadequate for the settlement and people from other settlements also tend to move in the vicinity of the borehole. Traditionally in the past the remote area dwellers in Botswana have relied for their water intake on wild tubers, roots and melons and in some cases on hand-dug wells and seep-wells which is the water collected in shallow ground depressions (pans) after rains. In recent years, such settlements have been provided drinking water by the district councils which is brought in by trucks. The supply of trucked-water besides being highly expensive, tends to be irregular and unreliable and return journeys on deep sand tracks sometimes exceeds 100 km. The progress on these tracks is generally few km per hour and results in frequent breakdown of equipment, high cost of maintenance, and leakage and spillage of water from the tanks. In 1982 a Joint Advisory Group on Desalination for Remote Area (JAGDRA) was set up with the aim to investigate and develop appropriate technologies to provide drinking water to remote area dwellers by in situ desalination of available ground water. The group lead by the Rural Industries Innovation Centre (RIIC), Kanye, consisted of representatives from the Ministry of Local Government and Lands, Department of Water Affairs, District Councils and the Botswana Christian Council. After years of investigations of different technologies, which included wood-burning stills, solar stills, night sky radiation still and reverse osmosis, the solar desalination of water has been found to be the most appropriate technology. Two types of solar stills, the modular Mexican still and the brick-basin still constructed on the site have been developed and used at several locations within the country to provide drinking water to settlements of up to few hundred people. The findings of these investigations and developments have been published by RIIC, Kanye from time to time (RIIC 1987, 1989, and 1991 and Yates et. al. 1990). In this paper we present a new design of a basin type solar still for application under Botswana conditions. The main feature of the new design is to recycle the latent heat of condensation of water vapour to pre-heat the saline water for the still. This results in more than doubling of the distillate yield per unit area of the basin.

A NEW THERMAL-ELECTRICAL SOLAR STILL

The still consists of a flat base basin, blackened inside to hold the saline water. The basin is covered with a horizontal glass cover as against the slanting glass cover in a conventional basin type still. Water vapour produced from the absorption of solar radiation by water in the basin is pumped out with a low-power exhaust fan and is passed through a water cooled condenser coil. A 100 W fan per square metre area of the basin is used. The distillate is collected in a tank connected to the other end of the condenser coil (Fig. 1). The coolant in the condenser tank is saline water which is pre-heated from the condensation of water vapour and is used for the next batch of recharge for the basin. As the coolant in the condenser tank heats up, there is evaporation inside the condenser tank also. These vapour are condensed on to the cover of the condenser tank and drip down a central tube into the distillate collection tank. There is a small loss of water vapour which escapes uncondensed. This loss depends on the water temperature near the bottom of the condenser tank. The electrical power needed to operate the exhaust fan can be provided from a photovoltaic (PV) panel. With a 10% efficiency of the panel, a 1 m^2 PV panel is sufficient for the 100 W fan. Solar distillation being a day-time activity, the sizing of PV panels and providing of extra storage is not crucial to this application. The advantages of this still over the conventional still are:

(i) The latent heat of condensation of water vapour is recycled to pre-heat saline water for the still. This gives a higher thermal efficiency for the system.

(ii) The glass cover does not heat up due to direct condensation of water vapour on its underside. This results in a larger temperature difference between the glass cover and water in the basin. Since the rate of evaporation from the basin

depends on this temperature difference, one gets faster evaporation of water from the basin.

(*iii*) The air under the glass cover is no longer saturated with water vapour. This also results in a faster rate of evaporation from the basin.

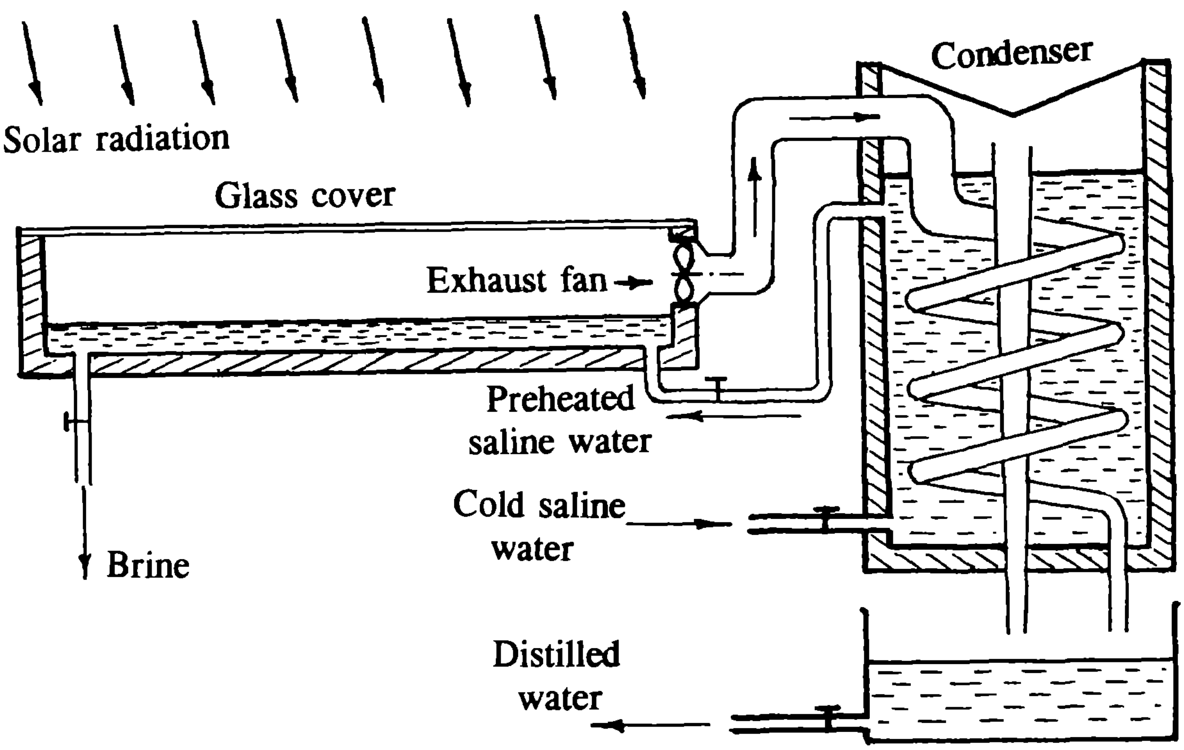

Fig.1: Schematic design of the new thermal-electrical solar still.

(*iv*) It is estimated that the capacity of the condenser tank should be about ten times the capacity of the basin (Nijegorodov et. al. 1994) to achieve best thermal efficiency of the system. With such large quantities of pre-heated water the still can be operated 24 hours a day to produce distilled water by filling the basin up with pre-heated water from the condenser. However, in that case some provision for electrical power either in the form of storage batteries or from the mains will have to be made to operate the exhaust fan.

(*v*) Since the water vapour does not condense on the underside of the glass cover, it is conveniently fixed horizontally on the basin and there is no need to have distillate collection troughs on the sides of the basin. This simplifies the design and installation of the basin and the glass cover.

Preliminary testing and investigations have shown that the new thermal-electrical solar still with a basin area of 1 m^2 and a 100 W exhaust fan yields 1 l of distillate per hour at noon-time. The yield from a conventional still under identical conditions is found to be 400 cc. This shows an improvement by a factor of 2.5 in the distillate yield. We had used mains power to operate the exhaust fan. If the use of a 10% efficient PV panel is assumed, a 1 m^2 PV panel will be required to operate the 100 W exhaust fan. In that case and in terms of the total solar radiation intercepted by the complete system the efficiency of the thermal-electrical still turns out to be 1.25 times the efficiency of the conventional still.

DISCUSSION AND CONCLUSIONS

In terms of the distillate yield and overall efficiency of the system, the new thermal-electrical solar still has a clear advantage over the conventional still. However, with the incorporation of an exhaust fan and PV panels into the new design, the installation and maintenance of the new still require a different level and nature of technical skill. Once the system is installed and commissioned the PV panels and the fan can run reliably and nearly maintenance free. The major daily maintenance is only for the still basin. Like other stills, the basin must be kept free from the deposition of salt and must be kept filled with water. Since with the new thermal-electrical still less than half the basin area is required to produce the same amount of distillate per day as compared to the basin area of a conventional still, the daily maintenance work load will be reduced significantly. In view of these advantages the new thermal-electrical solar still warrants field testing of its applicability under Botswana conditions. Its cost effectiveness as compared to other options available, social adaptability of a new technology in the traditional-rural communities and technical skill availability for installation and maintenance of the new system also need to be assessed to prove its potential for use in Botswana. Since the new still provides distilled water and large quantities of hot water, it can also be considered for use in clinics and science laboratories in schools in rural areas where both distilled and hot water are in large demand. Clinical application will require certain parts of the system to be made of high quality steel or glass.

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WATER SUPPLY AND CHOICE OF APPROPRIATE TECHNOLOGY IN BOTSWANA

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ABSTRACT

Water is critical for sustaining development in Botswana. Special consideration must therefore be made towards ensuring the sustainability of water resources. Population growth must be met while maintaining the standard of service and increasing coverage with a long term economic commitment To obtain a sustainable level of future water supplies, urban, rural and land issues must be considered. Although the urban water supply answers for more than 40% of the total future demand, discussions in the paper are concentrated on rural and lands area water supplies It should be emphasized that sustainable development can only be achieved through the decentralisation and privatisation of water supply services and the creation of local industries based on local artisan and professional skills development. The technologies adopted should be simple, durable with of low maintenance and repair demands and suitable for community management.

Although this approach will support diversification of rural income generation activities by providing the opportunity for small scale service industries creation, considerable obstacles to this development are likely as local people have never been geared for community participation in water supply provision Neither have they been faced with the fact that water is an economic product, and should be valued. At present government are mainly financing all water supply activities - which will persist until decentralisation and privatisation programmes are fully established. To reduce government expenditures and water resources, water services should be paid for or contributions in kind made by users in one way or the other Regular evaluations of the state of art should be made and clear specifications on the range of technologies appropriate for the job provided, in order to identify the best options for providing sustainable yields that meet the communities needs. Policies and recommendations agreed should be communicated throughout the government system and also made available to both the local communities and private sector.

INTRODUCTION

The Botswana environment is harsh and in terms of water supply the climate presents a considerable challenge for the people involved in the water sector. Water is scarce, and the national annual demand projected to increase from 135 million m^3 today to a total of 350 million m^3 in 25 years (BNWMP 1992) will be difficult to sustain. Permanent water shortage - higher amounts of evaporation than precipitation, regular droughts, groundwater mining due to limited recharge, are all related to natural climatic conditions for which the water supply system must be designed to cope.

About 60% of the population live in rural villages or smaller communities and use about 20% of the water available - figures that are rapidly changing with a growing proportion of water resources being used for meeting the expanding demands of the urban population. A tripartite settlement pattern between village, lands area and cattlepost living is still maintained. The latter two are not regarded as permanent. Most villages will have over 30% of their population in small semi-permanent rural settlements in the future. People and livestock are mutually inter-dependant in the lands areas, and hence drinking water is directly linked to watering of livestock. Livestock raising is likely to remain the principal source of rural income for the majority of the population.

Water provision in Botswana involves a mixed approach, where central and local Government share responsibilities for services. The programme to provide all villages with reasonable access to safe water has been a tremendous task. The objectives of water provision for village households with access to water points within 200m, and the ongoing evaluation of lands area water provision are worthy goals in a developing country context, but need to economically realistic. Water supply provision is officially limited to villages at least 5 years old, with a minimum of 100 households or 500 inhabitants and having been under the control of a continuous recognised traditional authority. These conditions are not always however, being met, and many smaller villages and settlements are becoming eligible for water supply programmes. Extended water supply provision has, nevertheless, been constrained by the need for rehabilitation of existing schemes. Extending water supplies into new villages and settlements are mainly implemented using a reticulation network standards with standpipes, an elevated storage reservoir and engine powered supply.

WATER TECHNOLOGIES - THE STATE OF ART.

The successful affair between Mrs Mono and Mr Lister.

Over several decades Mono pumps powered by Lister diesel engines have been widely promoted and adopted as "**the solution**" for water supply provision in Botswana. This has been a very successful approach as a constant production and operation quality and reliability has been achieved. This has mainly emerged from the establishment of a government policy which allowed the creation of a private supply and maintenance market. This concept has proven to be adequate for the large range of uses present. A support structure including the design/ installation/ repair/ maintenance and training of local staff and caretakers, has been established. The great versatility of diesel engines makes it difficult to find a better power source. The major disadvantage of this system has been its operation and maintenance cost. A pumper has to be trained to take care of the engine and pump, which together with fuel costs represents the main part of the total recurrent costs. High transport requirements/costs due to the level of service and monitoring needed also do not favour this option for applications in rural areas. Further, overall system efficiency is normally as low as 6-10%.

Renewable energy systems - The alternatives which still remain on the shelf.

Renewable energy systems include; hand, solar and wind pumping applications. A major study , Botswana Renewable Energy Technology Project (BRET), was taken during 1985-88 aimed at establishing the future potential of renewable energy systems on a technical and economic basis. When the project was finalized its recommendations were not implemented and no follow up from government has been made.

RENEWABLE ENERGY TECHNOLOGIES: State of the Art - The RIIC Perspective.

Major achievements in renewable energy technologies include the following:

Windpumps

Rotary windpumps are at present able to pump from 200-300m depth, however yields at this depth are limited to 5-8 m^3/day in average windspeeds(3 m/s). In the range from 10-100m depth several options are available which will provide between 10-30 m^3/day again based on average conditions.

Windpumps are designed to be ultra-reliable needing a very minimum of maintenance and attention. They are expected to run unattended with only minor service once annually and major service or significant breakdown only after ~80.000 operational hours, which is 4 to 10 times the span of a small diesel engine. Inevitably they are expensive in relation to their power output, because of the robust nature of their construction. However the minimum recurrent costs make them a highly viable option. The major constraint remains with the available wind speeds. Findings from early preliminary studies were discouraging and suggested this option did not have any significant potential. Recent by utilising more data on wind regimes and new findings that suggest an increase in available power can be made by increasing tower height - have changed the situation.

The available power increase is proportional to the increase in wind speed cubed ($P \sim V^3$), consequently average windspeeds alone cannot be used to determine the viability of windpumps. This may be illustrated by using a wind pattern density function which may show that though *above average* windspeeds are less occasional the resulting total power is higher than that provided by the same duration of average windspeeds. The average available power will hence be found to be higher than that indicated by the average windspeed. Overall system efficiency which varies with the design concept and available windspeeds, ranges between 5-15%.

Handpumps

The handpump option was referred to as the best low cost option for smaller yields by the BRET-project, and can still claim this position. The need for standardisation of handpumps, for covering a wide range of applications, has already been acknowledged by all Ministries and other involved organisations. Another major objective is to improve dissemination, reduce confusion and the create a supply network. However, standardisation is not always adhered to at all levels. Pumping equipment today, offers a range of operational modes, - traditional direct lift and lever action which are able to pump at a total head up to 110m, - forced lift beyond the pump head and transport through pipes to water reservoirs, all of which are highly reliable and low maintenance systems. Still handpumps are operated by hand - which will in case of reticulate village level water supply systems will require an operator, as water has to be pumped into a reservoir - knowing that the community members will only cater for their own need which cannot be seen when pumping into a reservoir or through a pipeline from outside the village into a discharge system. The costs of an operator represents a major financial requirement compared with investment- and maintenance costs System efficiency can be as high as 93% (using a special valve system), normally efficiency is about 50-60%.

Solar pumps

Solar pumping systems are still expensive compared to other systems and should not be used if total pumping heads exceed 150m or the power required exceeds 1-1.5kW as the numbers of panels needed will be far too expensive compared to other systems. AC and DC systems are available. DC systems tend to be more expensive on the pump side, however, they have a higher total efficiency, demand smaller PV (photo voltaic) arrays and have lower recurrent costs than AC systems. AC pumps utilise conventional electric motors which are of lower price but have higher maintenance demands.

Battery systems are extremely inefficient, and require deep cycle batteries which are expensive In addition, local climatic conditions may adversely effect their life and efficiency Using inverters to change D.C. to A.C voltage also places reliance on a battery bank for power storage (often the inverters cannot operate without a continuous power supply). Inverters (max 80% efficiency) are one of the most vulnerable system components when converting between DC/AC power. These units are rated for the startup surge which normally will be 4-6 times the systems operational demand. Investments in reliable units are critical as both the power rating and operationa reliability are linked with highly expensive units Employing power conditioning to convert voltage places emphasis on regular maintenance by qualified technicians. Coupling a hybrid system with a standby generator requires the system to be regularity serviced. An important factor is maintenance of the array, being mainly the cleaning of the solar panels to maintain panel efficiency. Overall system efficiency varies with the design and the components used. Inverters (DC-AC) cause the major loss of efficiency Total system efficiency ranges between 1-10% Options which require less maintenance and use less power conditioning equipment are the better long term solution

Windgenerators for water pumping.

A wind generator is being tested at RIIC. If suited to conditions in Botswana this will be the cheapest and most effective alternative power source available. Wind generators are more cost effective than P.V If limitations concerning the availability of wind all the year round exist, then a solar/wind hybrid could be very easy to install. This harnesses energy from both wind and sun to provide power, making it a very reliable and efficient source for remote water pumping.

Comparison of Renewable Energy Technology Alternatives.

General system costing comparisons must be based on assumptions as there has been no comparative evaluations made in Botswana. Table 1. indicates costs for a 1kW system operating at 50m depth (note that 1kW systems will yield according to the system efficiency and yield will necessarily vary with available power over the day).

As an illustration of the latter a solar system cannot solely be compared on a power input basis (array size) as a DC system may have higher efficiency and hence need less power to provide the same output as a AC system

Other Technologies.

Water treatment systems.
Where saline groundwater is found, supply systems are often limited to desalination Passive distillation with solar stills will provide pure water - at a very limited yield (4-10 l/d per unit) and require regular maintenance

TABLE 1. Technology Cost Comparison.

TECHNOLOGIES	INVESTMENT COST (Pula)	ANNUAL RECURRENT COST (Pula)	YIELD m3/hr exp yield maintenance
Engine powered			
Engine ST1	P 9000	P 3000	3-10
Pump/head/coll	P 6500	P 500	
Ancillaries	P 4500 (house /frame)	P14000 (labour)	high
Installation	P 5000		high
TOTAL	**P25000**	**P17500**	
Wind Pumps			
Above ground	P14000	P 500	0-8
Pump/head/coll	P 4500	P 500	
Ancillaries	P 6000 (storage+lab)	P 500 (labour)	low/medium
Installation	P 4000		low
TOTAL	**P28500**	**P 1500**	
Solar Powered AC			
PV arrays	P25000	P 200	0-10
Inverters	P 5500	P 700	
Pump	P10800	P 500	medium/high
Ancillaries (batt/cabl/pipe)	P 3500	P 2500 (labour)	medium/high
Installation	P 5000		
TOTAL	**P49800**	**P 3900**	
Solar Powered DC			
PV arrays	P25000	P 100	0-10
Pump	P14500	P 500	
Ancillaries	P 2500	P 1500 (labour)	medium/high
Installation	P 3000		
TOTAL	**P 45000**	**P 2100**	low
Handpumps			1-2
Pump	P5000	P 100	
Ancillaries	P 500	P 5400 (labour)	low
Installation	P1000		
TOTAL	**P 6500**	**P 5500**	low

(This table can only serve as an indicator).

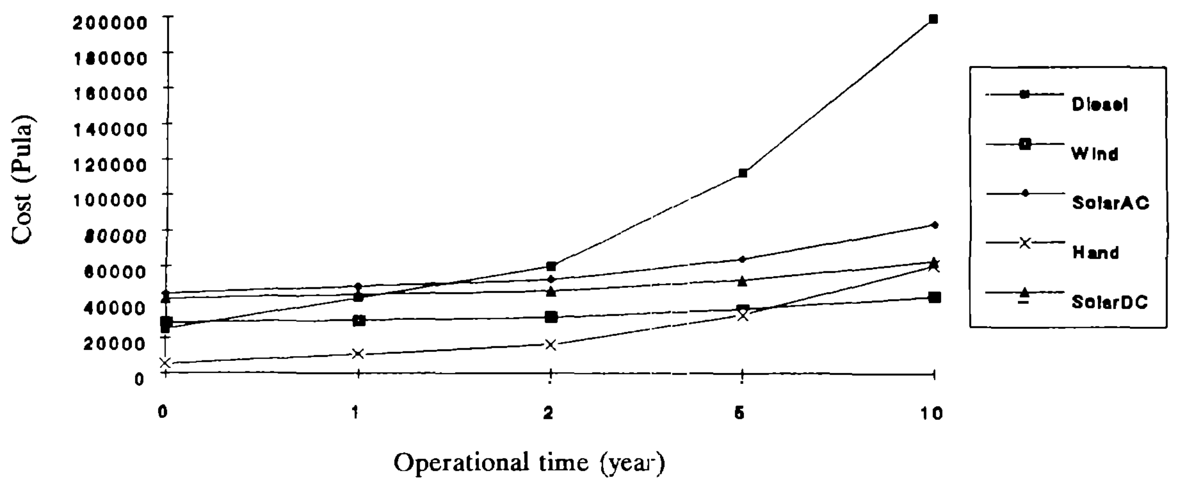


Fig. 1 Comparison of different technologies.

Forced desalination has been tested through two different technologies; low pressure reverse osmosis plants - which has produced encouraging results, and electro-dialysis which has not been as successful. Soon we will see a high pressure reverse osmosis plant in operation - this representing the upper range of this sophisticated technology. The introduction of these technologies has given special consideration towards repair and maintenance demands - which still have to be quantified.

Reed beds are being investigated as a biological systems for treatment of municipal, industrial and private waste water. Water quality acceptable for horticulture watering may be achieved. A project is at present being implemented by RIIC in Maun.

Rainwater catchment

A large scale catchment project using runoff from the side of a pan has been implemented at Zushwa in Kgalagadi District (Gould and Gurusamy - paper by Petersen et al. 1993.). The system has, however, never been fully operational as a bowser supply service has been maintained from external resources.

Sand Rivers.

Since sand river water storage capacities are substantial in parts of eastern Botswana, several abstraction systems have been developed from low yield domestic applications to high yield commercial farming systems. However the limiting factor is the local river conditions and the need to limit abstraction points in one area to sustain a storage capacity throughout the dry season.

PROBLEMS

Awareness and knowledge

Awareness of technical options in the water sector or indeed a general knowledge of appropriate solutions is very poor, both at government and community level. Information channels both between government and communities as well as within government bodies are being neglected and there appear to be few means for information dissemination or feedback. Evaluation of existing systems is limited to aspects regarding their inherent performance level. Alternative solutions are not in general being widely researched since existing system are presently found to be affordable and meet expected service levels. Evaluations are being undertaken by external consultants on contract basis at high cost.

There is thus felt to be no need consider alternative solutions, as this will create confusion amongst the parties involved and if adopted only increase government support commitments. A minimum investment in local participation and responsibility is maintained as this is expected to be of high cost and will lower standards if implemented. Field officers are therefore left with the well established systems, regardless of its capabilities or performance.

The communities, which have government officials as their major source of information, are not always well informed or aware of current technical developments. Limited participation in the water supply systems reduces the community responsibilities and involvement to a minimum. Government is expected to cater for all aspects from technology choice and initial investment, to the operation and maintenance costs.

Private sector Capabilities.

The private sector in rural communities presently cannot cater for a decentralisation of water supplies, either through technology support or due to knowledge of operation and maintenance. Firstly the skills and technical knowledge level must be carefully addressed if a change in policy is to be made. Secondly the high level of service expectation established through the present implemented policy, will initially limit private sector opportunities and willingness to cater for such services, as their technology investment in production quality will outreach their initial skills and abilities. It is a political challenge to redress the water supply policy towards services which both the communities can benefit from and interact with a sustainable manner, rather than provide the popular choices of maximum service as long as the economy and resources can allow for such provisions.

The Tripartite systems.

Since people are moving within a tripartite settlement pattern, water provision in the different homesteads must be clarified. Here follows the problem of whether people should be encouraged to remain in their respective lands area to improve agriculture output - and hence find domestic water available, or water provisions should be limited to the village/settlement level only, as at present.

Consumption Habits.

The consumption habits influenced by an efficient commercial sector and lack of local know-how, favours a prioritization of turn key products rather than those which are locally manufactured.

SUGGESTIONS

i. Clean water is a pre-requisite for health and development, and an economic product which has to be valued. In order to save resources and maintain sustainable development water services have to be paid for, or contributions in kind should be made by the users in one way or another.

ii. Low yield technologies are presently shelved by the government, emphasis is placed on existing water supply schemes providing high service levels and yields. Low yield technologies are not considered as they are not expected to meet the general standards. As present state of the art low yield technologies seem to have reduced the gap of service level capabilities compared with diesel engine systems the government should reinvestigate the potential and capabilities of the options available - to identify criteria under which they may be evaluated and possibly implemented and adapted within a broader framework for community development based on local participation in the water service sector. The evaluation of technologies should be based on the appropriateness for the job, for the community and for the resources available. The choice of technology should be *needs driven* not *technology driven*. This basically boils down to selecting options available which will satisfy the need, based on available resources and a overall economic judgement both involving investment/recurrent costings.

iii. The lack of awareness and knowledge of appropriate technology options within the government as well as on a community level must be addressed. Community involvement will have to be increased and information channels strengthened and formalised. Information channels must be made two way to cater for dissemination of knowledge and feedback to policy/decision makers to enable continuous reviews of standards and procedures to be implemented.

iv. In establishing the recommended technology ranges, - policy makers and technical advisors both from within and outside the government must be involved. Established recommendations must include clear product specifications, - and resource centres appointed to provide inspection and assure service/manufacturers certification before entering the support structure.

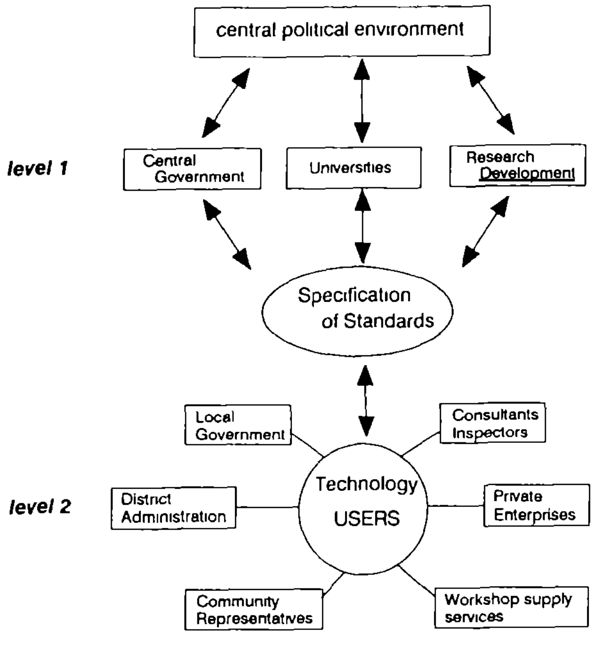
v. The private sector cannot be involved in water supply services without programmes addressing this issue being established. Government cost reductions will be achieved as local manufacturers and services contributions are substantially increased. The coordination of private sector activities is a crucial factor in the success of low yield technology implementation. The balance between providing a high level of technical assistance and not interfering in the supply demand pattern must be found.

vi. Local industries need to be organised and operated in a clearly defined regulated framework. Standardisation and stable policy are essential conditions. Public sector involvement will specially require *quality control and quality assurance*. Certification will affirm that the specifications are adhered to and this may be achieved by involving independent inspection agencies. Established workshops should be identified for certification of water supply technologies manufacture. To enable immediate quality performance highly skilled staff should be seconded both at the administration and manufacturing levels for the initial period. Specifications towards production resources, machinery and skills must be available to ensure development of a competitive industry.

vii. In a limited market such as Botswana, local manufacture and services can only succeed if all involved parties direct orders towards their home industries. Channelled order volumes based on rural water supply will ensure economic viability for small scale industries, which will also be an incentive for income diversification.

viii. A structure defining all relevant players involved in water supply programmes is hereby proposed;

Fig. 2 Proposed Institutional Structure For Water Supply Programmes



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QUESTIONS AND COMMENTS

OPENING SESSION

OPENING PAPER:- Mr B.B. Khupe, Director, Department of Water Affairs

"Integrated Water Resources Management in Botswana"

G. Nilsson (Sanitas)
Has the department considered the pumping of water from the Limpopo (backwards) to Botswana? Water importation whether from the Limpopo or Zambezi should be considered or what about from Bangladesh or Antarctica!

Response: This would be quite an expensive undertaking.

J. Gould (UB)
You have mentioned in your paper that after 2020 Botswana will need to look towards the Zambezi Basin for its water requirements. Is it not unwise to base future planning on this source given that Zimbabwe, Zambia, Republic of South Africa and other Southern Africa nations with bigger populations and water demands are also keen on developing Zambezi River sources? Is there not therefore a risk of conflict over Zambezi Water Resources?

Response: There is a need for discussions and agreements with other basin nations to agree on how the water resources can be shared.

R. Silitshena (UB)
In reference to SHAA, does water consumption really decrease when private connections replace the use of stand pipes.

Response: Yes. Water is free at the standpipes and there is a lot of wastage.

J. Arntzen (UB)
Will there be a point in time in urban areas especially Gaborone when people will be encouraged to settle elsewhere due to population increases?

Response: There are other factors apart from water demands to consider when discussing settlement trends. The Ministry of Local Government, Lands and Housing under the National Settlement Policy is trying to encourage settlement in other areas.

KEYNOTE ADDRESS: Professor M. Falkenmark

"Successfully Coping with Complex Water Scarcity - An Issue of Land/Water Integration"

M. Hagos (MLGLH)
The aridity runoff graph is based on climatological parameters alone while geology and topography also influences the runoff, how accurate is this tool for water resources management?

Response: The map shows the principal differences between types of climatic conditions. The problems of land impermeability is not included in the map, just the partitioning between what goes back to the atmosphere and what goes to feed aquifers and rivers. The diagram included a number of validation studies made by a Professor in Hungary, but the studies were limited to around 50 catchments in Europe. There has been no validation made with data from other continents so far.

G. Nilsson (Sanitas)
Botswana is rich in water. Land impermeability should be taken as an asset. Soil conservation could be used to avert the loss of water from the soil. Impermeability is a basic asset for water concentration. Seventy-five percent of the rain can be concentrated so as to pass through just twenty-five percent of the land by using the strip farming method. Wasted water, 1 000 000 cubic metres from Gaborone can feed 10, 000 hectares with permanent strips 1 000 cubic metres/hectare as supplementary irrigation. (With drainage pipes in rural areas you can filter millions of cubic metres of waste water).

J. Arntzen (UB)
The paper is not explicit of the time frame. Considering the present population growth, water storage etc. how long will Botswana remain like this? When will the shortages be absolute?

Response: The population growth is known up to 2020-25, during this time Botswana is going to stay in this interval.

KEYNOTE ADDRESS: Mr J. Krook, Consultant, DWA

"An overview of water resources development in Botswana"

M. Falkenmark
There is no contradiction between her water scarcity profile and what was discussed by Mr Krook. The problems include biomass production under erratic rainfall, drought incidence, redistribution in time and space (in comparison with the National Master Water Plan) but not really the total amount available in the rivers. A big problem is however the high dependence on river runoff from other countries.

Observation:- Recommendations on use in water plans are always 5-10 percent too high.

QUESTIONS AND COMMENTS ON PAPERS

THEME 1: SUSTAINABLE WATER RESOURCES MANAGEMENT

Paper 1: Maunge F. (WUC) and Taleyana, M.(DWA)
"Management of Water Supplies (Urban and Rural Aspects)"

No comments/questions.

Paper 2: Makosha, Z. (DWA)
"Water Demand Projections; the Case of the Botswana National Master Plan."

The question was asked as to whether there is any discussion in the BNWMP on how to reduce water demand in the various sections; i.e through reuse.

Response: Re-use and recycling is one of the strategies for reducing demand.

Paper 3: Hagos, M.A. (MLGLH)
"Sustainability and Cost Efficiency of District Councils Water Supply Services".

With regard to full cost recovery, one participant wondered whether rural people could afford to pay appropriate tariffs.

Response: Those applying for private connections seem to be in a position to pay.

Another participant commented that full cost recovery has been tried in many countries but does not seem to have worked. Implementation is the problem.

Response: Communities should also be prepared to contribute something towards their water systems.

Paper 4: J. Gould (UB)
"Longterm Water Resources Management in Botswana: The case for controlling Demand".

K. Selotlegeng (MLGLH) asked: Given the evident scarcity and inadequacy of our water resources in Botswana, what is your opinion on the introduction of water saving devices in the construction industry? In particular, the use of low volume flush toilets and other water saving devices in clinics, hospitals, schools and government offices to conserve this meagre resource?

Response: There are a wide range of ways in which schools, clinics, houses etc. can be designed in much more efficient ways to encourage water saving. (see paper for some examples). However, more research and pilot studies are needed to test the feasibility of some of these technologies and government is in an ideal position to influence this development, both at institutions and for the BHC housing stock.

J. Krook asked the presenter whether he had any specific information on per capita consumption in the South Australian example he mentioned?

Response: The presenter responded saying he would have to consult the booklet for specific figures.

F. Maunge (WUC) made the following points:-

(i) A study done by Steward Scott in 1988 showed that there was cause for concern about pollution at Shashe Dam as the storage had reduced by 4% due to this, after 15 years. The tendency is for the dam to fill during heavy storms and suspended particles are carried across the spillway.

(ii) Consumers who can afford swimming pools generally have their water bills paid for by their employers as a benefit. An example of this is the BCL mine in Selebi-Phikwe which pays water bills for its employees. Under these circumstances, the consumer does not always feel the impact or the direct cost.

(iii) The WUC commissioned a water use and affordability study 2-3 years ago and concluded that there was no apparent relationship between increased tariffs and reduced demand. Future studies may, however, conclude otherwise.

(iv) The idea of collecting stormwater in tanks is fine but people need to understand the issue and be prepared to finance it. The tendency in Botswana is that people can afford (thus far) more expensive and luxurious services so that water bills are perhaps not a problem.

Response: The presenter noted that with respect to water people in urban areas are given a good deal relative to rural dwellers, due to enormous government funding for urban supplies. Hopefully, through the Lands Area Water Supply Programme, rural dwellers may also receive a greater share of government support and get a better deal in future.

Paper 5: <u>Cashman, A.C. (Parkman)</u>

"Drought Management in Namibia 1992/3, with Special Reference to Water Supply and the use of Public Awareness Campaigns".

J. Arntzen (UB) With regards to the emergency water supply programme, did you have local requests for water which did not fit into land-use plans and could cause environmental problems in the longterm?

Response: In the Ovamboland case, there was no formal land use planning and because of the pressures on land i.e rapid population growth rates and densities, the environment had been negatively influenced already. He emphasized that when people are desperate for water, it is difficult to say no, on environmental grounds.

B. Rydtun (RIIC) asked how community participation is facilitated and what is its impact on living patterns as diversification of income generating activities and cattle raising practises can be seen?

Response: In our case, community participation was facilitated through the running of water committees drawn from the communities, who evaluated requests and complaints brought through headmen. It is these water committees which then recommended the action to be taken. No impact on changes in livelihood patterns was observed because the time had been too short.

M. Hagos (MLGLH) observed that public awareness from within a community takes a long time to obtain results, while in the meantime, there is strong pressure for service provision. Should we wait until the public is aware or should we also take external measures?

Response: The presenter noted that one measure on its own will not bring about change, instead, there is a need to look at a range of initiatives to do so. However, changing of peoples attitudes, approaches and usage patterns takes a long time.

THEME 2: WATER RESOURCE DEVELOPMENT AND ENVIRONMENT

Paper 1: **B.U. Bhebhe (DTRP):**
"Changing Settlement Patterns and Impacts on Water Supply Provision".

Question: Doesn't the government control the provision and building of facilities like schools and clinics?

Response: Though this is usually the case, political pressure also plays a role in this.

Comment: In Zimbabwe where a similar problem was faced after independence, it was addressed by forming planning committees comprising of representatives from the relevant ministries or departments in consultation with District Councils. The planning committees identified and even prioritized the building of infrastructure. Even funding was decided by these committees. A similar approach was suggested for Botswana.

Paper 2: **I. Mabua, K. Mokokwe and K. Busch (DGS):**
"Protection of Water Resources Against Pollution by Vulnerability Mapping".

A. Bird (Aquatech): Are you using Geographical Information Systems for preservation and manipulation of data?

Response: Most of the data is on paper, the hydrological data has been computerised, the soil maps are available.

A.Bird: Are you proposing to carry out work around the Selebi-Phikwe mine site?

Response: Work begun in Lobatse then it will be progressing up north.

J. Krook How applicable is a vulnerability model developed in a humid country where the groundwater recharge is of the order of 50-100 times large than in Botswana?

Response: The model has been adapted to Botswana e.g factors used in Botswana in consideration until the water level is 1.57 compared to 1.0 used in Germany.

K. Selotlegeng (MLGLH) It is fairly evident that when development programmes were planned in the past they did not take into account the need for environmental impact assessments. To ensure that measures proposed for vulnerability to aquifers are effected, what practical structure remediation arrangements do you suggest for future developments and what retrofitting corrections for previous mistakes made do you perceive?

Response: Those areas that have an environmental impact have been take into consideration and where possible some of these sites will be shifted to other areas.

Paper 3: **J. Arntzen (UB)**
"Environmental Economic Aspects of Sustainable Water Management in Botswana".

F. Maunge (WUC) If the estimates for schemes is to include environmental costs, donors/financiers may have a different method of estimating and therefore may not necessarily agree with the method of economic analysis presented?

Response: There are various standard techniques for calculating environmental costs; and donors are putting a lot of emphasis on incorporating environmental costs in project appraisals so this should not be a problem.

Paper 4: **F.T.K. Sefe (UB)**
"The role of EIA in Water Resources Projects as a tool for joint management of both the environment and water in Botswana".

A. Cashman (Parkman) Should EIA be applied to policies or projects?

Response: You cannot separate the two. Since it's much easier to affect projects, then it should be especially applied to projects.

J. Krook The decision to opt for Bokaa in favour of Kolobeng and Metsemotlhabe was entirely based on economic considerations P20 million for the former verses P50 million for the latter option.

K. A. Selotlegeng (MLGLH) In your EIA diagram where do you propose mitigation measures should be introduced if a project with potentials for possible degradation impacts is established.

Response: If you decide to implement a project you would also take care of compensations and mitigation.

A. Bird:(Aquatech) Detailed post-construction environmental monitoring programmes were drawn up for the Bokaa and Kolobeng and Metsemotlhabe studies that were very comprehensive. They included immediate, medium term (up to 5 years) and long term monitoring of both the human and natural environmental for both compensation, management and research uses. Cost estimates for this were also included, where possible, and although these may not appear in the final version of the project they were certainly in the Draft. This illustrates the weakness in reviewing EIA work by just reading reports, it is important that researches go and talk to the people who actually carried out the work in order to get the full story. Only a fraction of the real work is normally reflected in the report and the emphasis may well be different.

In 1988 when I first arrived in Botswana to carry out EIA studies at Bokaa there were no environmental guidelines or procedures in place for such work. At the time this did not matter that much, as Botswana was well ahead of most other countries in putting environmental issues to the fore of may studies and locally developed appropriate analysis techniques were being used. Many of the specialists used for such work had considerable relevant experience and were able to work effectively without formal guidelines. Detailed guidelines were however drafted for land acquisition and compensation procedures during 1988 and at this time work was on-going with the National Conservation Strategy.

However, when returning to Botswana in January 1994, having been away from the country for nearly three years, it was disappointing to find that still no further progress appears to have been reached on enacting a coherent body of environmental legislation, including guidelines and procedures, to ensure EIA work is carried out in a consistent manner and to a minimum international standard. As a result Botswana is now falling behind many other developing countries in this field. The situation has been made worse still by the policy of splitting the environmental component of water resources studies away from the engineering studies and giving it out as a separate contract. This is resulting in work not being carried out in the integrated and multi-disciplinary way that was previously the case. Whilst there may be genuine concern that there is a potential conflict of interest if the EIA work is included in the engineering contract, I feel the benefit of inter-disciplinary working far outweigh this. In any case it was always recommended that all EIA work should be independently reviewed to ensure that sound technical judgement had not been compromised by short term commercial considerations or an over emphasis on the engineering aspects of the study.

The real problem is that the implementation of large scale water resources projects in Botswana is carried out by institutions that are inadequately set-up to cope with integrated environmental work. The recommendation that an Environmental Liaison Officer be employed by WUC for the Bokaa Dam Project and that this person could then build up an environmental planning function within the organisation was never carried out. As a result much of the sound recommendations made in the Bokaa EIA study were not followed up, those issues that were looked at have tended to be tackled in a piecemeal and ad-hoc manner.Urgent action is now needed to address the institutional short-comings of the implementation of the environmental management aspects of water resources projects in Botswana.

Paper 5: A. Gieske (UB)
"Use of surface and groundwater in Botswana: Urban and Rural Aspects.

B. Rydtun (RIIC) Water quality improvement methods and low yield water supply technologies are a matter of awareness and knowledge. The existence of a variety of technologies researched and developed at RIIC do support this status.

J. Krook Deep storage has been extensively studied as part of the National Water Master Plan. Artificial recharge is quite a good complement but where is that done in Botswana?

G. Gabaake (DWA) Artificial recharge of the Shashe Wellfield in Maun has been considered in the planned project in Maun as one of the options which require investigation.

J. Krook The system yield benefit resulting from connecting the southern and northern sources is significant.

Response (A. Gieske): Recharging could also be considered. Although this is quite an expensive method and the water yield is probably low, successful recharge projects are being carried out all over the world. A pilot project is thus recommended.

K. Kalaote (DWA) It is suggested in the presentation that to make efficient use of a reservoir, provision should be made to trap all the water that spills from the dam. Does the presenter take into consideration the impact of the dam on down stream users.

Response: The effects of reducing spill have not been taken into consideration here, the mere fact of building a dam has enormous effects on the downstream users. These consequences should always be studied carefully.

O. Baoliki (MoA) How and where can you store water in your Shashe Dam chart (page 9) for use during short falls or during drought years?

Response: By studying artificial recharge (or cyclic storage) possibilities along the North-South Carrier.

M. Hagos: Artificial recharge is very ideal theoretically but it needs a proper site which will be difficult in most cases. Is your recommendation to infiltrate surface water technical and economically realistic.

Response: It is expensive and requires a lot of skill, the techniques of artificial recharge have to be carefully applied in order to avoid problems with eg. siltation, but possibilities should be studied in more detail.

THEME 3: APPROPRIATE WATER TECHNOLOGIES

Paper 1: Selotlegeng, K. (MLGLH)
"Effluent Re-use, Potential Water Resources for Multi-Purpose Utilization - Gaborone Case Study".

F. Maunge (WUC) Disagreed that the (effluent) resources were available at no cost to government, as it had to be converted to acceptable standards through treatment works to be paid for by government. There are also cultural obstacles to be overcome, and the risk of poor treatment. However, he agreed that it was a resource which could be used to defer at least Phase II of the N-S carrier.

Response: All that we are saying is that the resource is available. We don't have to ask for it, import it from other countries or any other water bodies, or the N-S Carrier. It is available right here in Gaborone at no cost.

Z. Makosha (DWA) Noted that effluent re-use is considered as one of strategies for meeting future demand for water. The BNWMP indeed indicates that re-use could postpone implementation of the N-S Carrier phase II, by up to four years. However, the North South Carrier (NCS) phase I is required to maintain or improve security of supply.

Paper 2: H. Masundire (UB)
"Waste water re-use and cultural eutrophication a case study"

K. Selotlegeng (MLGLH) Agreed that efficient re-use required establishment of the necessary infrastructural networks and that if raw sewage is discharged into receiving bodies then you will tamper with the fauna and flora resulting in anoxic conditions within the biotic system. To enhance effluent re-use, the city of Gaborone will within the next two years receive an activated sludge plant with a nutrient removal capability. For potable re-use it is proposed that water and effluent blending be carried out twice, firstly in the Bokaa Dam and secondly en route from Bokaa to the Gaborone Dam. It is also proposed that a pilot project be established to provide the water authority with a total waste water reclamation experience, before the overall concept is implemented nationally.

H. Masundire (UB) The main difference the Gaborone case has from the Zimbabwean case is that waste water is being discharge downstream so if advocating for re-use for watering parks and gardens, it may be easier. If you are advocating recycling, first of all the treatment works that are in place are not efficient enough to produce quality effluent that could be returned to the reservoir. If we did put in place adequate treatment works at Broadhurst or Phakalane, then we must cope with the cost of pumping the water upstream back to the reservoir which reduces the effectiveness of treatment. Certainly these factors must be taken into consideration.

Paper 3: M. Mphati (MoA)
"The role of the Ministry of Agriculture water development sector in water resources development/small dam design".

The question was asked as to whether proper management of a reservoir is a criterion for selection of the site at which to build a dam. Furthermore, how do you ensure that the dams are properly managed after construction. Finally, how does the Ministry of Agriculture limit the numbers of livestock using a reservoir?

Response: Farmers in an area express their need for water and make an applications through the usual means. After this, we examine sites which are suitable for dam construction. In terms of management, Ministry of Agriculture assists groups, not individuals, which are properly constituted which have a constitution which binds the group to look after the dam as it is being built and after it's completion.

Paper 4: Jain P.K. and Nijegorodov (UB)
"Solar desalination of water for remote, rural communities in Botswana: a new approach".

O. Katai (DWA) Asked what the area of the largest test unit was a present. He observed that it would be interesting to note the range of TDS (total dissolved solids) of water on which the test was carried out, as well as the total volume yield per hour?

Response: Test unit is about 1m2 area, but has not been tested in the field or used to provide drinking water for any community yet.

J. Gould (UB) Asked if there were any plans to pilot test the system. He also wished to know the cost of the new thermal-electric solar still?

Response: No detailed cost information is available as we are still in the test/experimental lab stage. However, it is hoped to field test the system in the near future, in cooperation with RIIC who have had practical experience in the field with these methods.

<u>GROUP DISCUSSION SUMMARIES</u>

<u>THEME 1</u>: SUSTAINABLE WATER RESOURCE MANAGEMENT

Participants:-

G. Gabaake (Chairperson)
E. Skoglund
J. Moyo
Z. Makosha
F. Maunge
J. Krook (Resources Person)
J. Gould
A. Cashman (Secretary)
N. Taleyana
O. Katai

1. Institutional arrangements: These are reasonably good but can be improved. Realignment of certain functions could be done through the creations of a policy making coordination body which would be responsible for the following:
   - planning policy
   - coordination
   - arbitration

   An <u>independent</u> water resources council has been proposed but other functions should be devolved to appropriate levels e.g. community participation.

2. Demand vs Resource driven water development

   Clearly a balance between the two approaches is required
   - need to secure water supply to underpin development
   - need to consider all costs/benefits while still meeting basic needs

   Need to balance demand with resources
   - use appropriate resources
   - achieve division sharing

   Flexibility of planning is also crucially important

3. Need to control demand
   - through tariff structures
   - widening the base of those who should pay
   - education and awareness
   - water has a worth
   - promotion of available water saving technologies

4. Conjunctive Use
   - Should be considered within the various constraints

5. Development of local expertise
   - to ensure long-term sustainability
   - emphasis on training therefore essential

THEME 2: WATER RESOURCES DEVELOPMENT AND THE ENVIRONMENT

Participants:-

P. Phofuetsile (Chairperson)
I. Mabua
M. Hemert
A. Gieske (Secretary)
K. Busch
J. Arntzen
M. Falkenmark (Resource person)

B. Bhebhe
K. Mokokwe
G. Hetolang
K. Kalaote
G. Ramontshonyana
A. Bird

It was felt that a core paper on environmental issues would have been useful to define the human and natural environment and their interaction with regard to water resources management. Theme 2 "Water Resources Development and the Environment" is obviously closely linked to Theme 1 "Sustainable Water Resource Management". Water Resources planning in Botswana is still in a state of flux with a lack of sufficiently trained multi-disciplinary personnel to deal with all environmental issues, although efforts are being made to improve the situation. Basic legislation and a set of rules for environmental planning are being developed in a proposal that is on its way from the National Conservation Strategy Agency to the Attorney General's Office.

However, pending finalization of the necessary regulations, it is unclear which projects are to be considered for Environmental Impact Assessment (EIA) and which Ministries should be involved. For example, should the Botswana National Water Master Plan Study have been subjected to EIA ? Once a set of rules is in place, EIA should be systematically applied to minimize unwanted side effects of the proposed water resources development.

A special effort is then required to initiate contact and communication between all the parties involved, which will be a slow but crucial process. Environmentalists are often to blame themselves because their response is frequently reactive and late. Public awareness of environmental issues in water resources planning needs to be raised and improved to ensure adequate local participation.

A number of specific issues was also addressed in the group discussion :

- The evaluation of local water resources should have the first priority in deciding on settlement growth potential and service provision. Government should take a stand on issues regarding the Lands Areas Water Supply. Village water supply technology should be improved by applied research leading to low-cost durable designs for hand pumps, dug wells, roof top catchments, haffirs, etc. More uniformity is required in the criteria for the provision of services to small settlements.

- Control of waste disposal sites should be improved in consultation with the District Councils, while raising public awareness with respect to surface and groundwater pollution problems. Thus far, the response of councils to the vulnerability mapping programme (Geological Survey Department) has been found to be very positive.

- When taking all environmental aspects of water resource development into account the price of water is still too low. While essential water use must be guaranteed, prices should reflect the priority of productive activities over non-essential use. In pollution problems, the guiding principle should be that the polluter pays. In determining water prices and the controlling effect of price on demand, demand curves are not well studied.

- Conjunctive use of surface and groundwater for the large scale eastern Botswana water supply projects could be looked into more thoroughly, because this could lead to more efficient use of dams and protection of vulnerable groundwater resources for future generations. Small scale artificial recharge pilot projects could be started in, for example, eastern Botswana and the Shashe Wellfield (Maun). Whether large scale conjunctive use projects will be technically and economically feasible, depends on demand and price developments in the near future.

THEME 3: APPROPRIATE WATER TECHNOLOGIES

Participants:-

M. Mphati (Chairperson)	P. Morgan (Resource person)
B. Rydtun (Secretary)	L. Linde
C. Grant	K. Wah
D. Disele	G. Chilume
R. Simon	H. Masundire

1. Rehabilitation and improvements of traditional water resources and the introduction of rain water catchment systems should be promoted:

2. Desalination: Various technologies for desalination have been tried and have been proven to be capable of supplying potable water. The group suggested that this programme be extended and expanded to those areas where no other viable option exists.

3. Recurrent cost of existing water supply schemes are a major constraint. Existing rural village water supplies should be evaluated in light of the existing range of appropriate technologies available in order to reduce recurrent costs and increase community participation.

4. In the introduction of new technologies information channels must be created and strengthened to cater for dissemination of knowledge and feedback to policy/decision makers to enable continuous reviews of standards and procedures.

5. In a city such as Gaborone, 18,000m^3 of waste water is produced everyday. Smaller, although still significant, amounts are produced by villages and even by individual households.

Group 3 recommended that:

(i) A clear policy, backed by the necessary legislation, be formed for waste water management at all levels in Botswana.

(ii) A local, regional and if necessary an international study be conducted to establish which technologies are available, adaptable and ultimately transferable to Botswana.

(iii) The existing authorities, involved in the provision of water and its disposal should be drawn close together to ensure an efficient and cost effective waste water management system.

SUMMARY OF DISCUSSION GROUP SUGGESTIONS

Z. Makosha (DWA) There was a general sentiment that environmental issues were not adequately addressed in this seminar. "Environment" must be defined so that the interaction between human activity and the natural environment be clarified.

1) There should be legislation and guidelines on EIA so that it is clear which projects require EIAs. (For instance the BNWMP should have been assessed along these lines/terms).

2) The system for the handover of projects between different government departments involved in the water sector needs to be improved.

3) For major water projects multidisciplinary studies and environmental work should not be divorced from the engineering work. (There is scope for an environmental unit within WUC for longterm monitoring).

4) Local expertise and capability with regard to EIAs and monitoring has to be improved. Water should be the first consideration in the development of settlements. All other developments plus facilities should follow water provision.

5) The Lands Areas Water Supply Policy should be implemented as a matter of urgency and appropriate technologies should be developed and made available.

6) There is a need to be strict as to which settlements qualify for water provision and so adhere to the stipulated definition of a village.

7) Tariff structures must be reviewed, especially in major villages where the price of water is rather low, due to heavy subsidy.

8) Links between government and private sector should be strengthened.

9) Government must control or monitor the use of water by mining authorities.

10) Groundwater recharge should be further investigated.

11) Demand should be balanced with the water resources available in the longterm.

12) Educational programmes needed to raise public awareness about water conservation.

13) Conjunctive use of surface and groundwater should be investigated.

14) Existing rural water supply schemes should be reviewed.

15) There is need for legislation on waste water management.

16) A study should determine appropriate technologies for waste water use.

SUMMARY AND CONCLUSION

Professor M. Falkenmark

Prof. Falkenmark began by identifying certain crucial preconditions; concepts; technologies and other insights which had been highlighted at the workshop.

Among the preconditions or predicaments she noted the following;

(i) General water scarcity in the country and the fact that most of the water seems to be exogenous and our challenge now, is to make use of the endogenous water;

(ii) The lack of dam sites makes it difficult to mobilize the water which belongs to Botswana;

(iii) The huge evaporative demands which create enormous losses from the surface water reservoirs and merit an interest for sub-surface storage of water;

(iv) Very limited groundwater recharge (in order of 20mm or less)

New concepts had she heard at the workshop

(i) 'Integrated network of sources' from the BNWMP.

(ii) 'National Water Conservation Strategy' - water has to be integrated more clearly into broader national conservation concerns. In the past, water conservation concerned mainly wetland areas only.

(iii) 'Vulnerability maps' and the role that they can play in the siting of landfills.

(iv) Water preconditions have to be taken into account in the settlement planning in order to avoid undue costs.

(v) What does 'environment' mean and how is it related to sustainability - there needs to be a dialogue between the development perspective and the protection perspective of these environment - sustainability concepts.

(vi) Concept of 'appropriate resources' appeared (possibly this refers to resources which are easy to mobilize).

A number of fresh techniques have been discussed have at the workshop;

(i) Rainwater collection; rainwater harvesting and rainwater catchment.

(ii) Artificial recharge - evaluation for the potential for this technique has been raised in the workshop, which would also open the possibility for conjunction use. The question now is what sort of constraints will limit the possibility to achieve conjunctive use for surface water and groundwater.

(iii) There has been much discussion of waste water reuse - especially for Gaborone. There is a call for a clear policy and legislation governing this.

(iv) Desalination of saline groundwater is to be promoted.

(v) In terms of institutional issues, a call for a policy-making coordinating body has also been made.

SOME PERSONAL CONCLUSIONS

I came to Botswana to hopefully get a clear idea of its water resources in view of perceptions that I brought with me from my comparative studies. One of my perceptions was that there is a scarcity of water for agricultural production but that there is plenty for societal production. But what is clear here is that most of that water is locked up in the imported rivers and can not really be considered as a water resource for Botswana yet. Unfortunately, the documentation provided for the workshop gives limited information on the water resources of Botswana, but plenty of information on the water demand. So my conclusion here is, that at present, even in a water short country like Botswana, water is seen as a technical issue. The settlements are planned without attention to water, and planning is demand driven. This means that at present, the modern society has not adapted to the water scarcity in this country. However, in the documentation there is, at the same time, a number of signs of a growing 'mental shift'. Mr Hagos in his paper stresses that availability must be given emphasis if sustainable development is going to be achieved. Mr Gould suggested that it is essential to keep consumption levels within sustainability levels. The working group discussions also showed that higher priority to water has to be given in the planning exercise. One of the key conclusions in the various working groups seems to be the necessity of raising public awareness of water as a resource which has a value, a resource which is vulnerable and will be polluted from polluting activities on the land surface, and a resource which is mobile and has a limited recharge.

Finally among the signs of the mental shift, I would like to include the desire to clarify the interaction between human activities and the natural environment and landscape. To clarify this interaction is fundamental in order to get the environmental impact assessment and attention to be paid to environmental side effects right from the beginning. This is essential.

CLOSING STATEMENT: Ms A. Edstrom (SIDA)

Thanked the organizers of this workshop for doing an excellent job. I would like to thank all of you who have participated in this workshop. We have had a very good turn out and I have been personally impressed by all the inputs made by resource persons, authors of papers and other participants during the discussions. During these two days several important recommendations have been made and I would wish that these will be implemented. This is often the difficult part.

PULA!

AUTHOR INDEX

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