LEVERAGING WATER DELIVERY

Irrigation technology choices and operations and maintenance in smallholder systems in Zimbabwe

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ABBREVIATIONS AND ACRONYMS

AEO	Agricultural Extension Officer
Agritex	Department of Agricultural, Technical and Extension Services
ARDA	Agricultural Rural and Development Authority
AREX	Department of Research and Extension Services
CWR	Crop water requirements
CROPWAT	FAO computer programme for calculation of crop water requirements
DAEO	District Agricultural Extension Officer
DERUDE	Department of Rural Development
DR&SS	Department of Research and Specialist Services
DWD	Department of Water Development
DIWD	Department of Irrigation and Water Development
EW	Extension Worker
EU	European Union
EIRR	Economic Internal Rate of Return
FIRR	Financial Internal Rate of Return
FAO	Food and Agriculture Organisation
GOZ	Government of Zimbabwe
IFAD	International Food and Agriculture Development
IMC	Irrigation Management Committee
IMT	Irrigation Management Transfer
IMWI	International Water management Institute
MRRWD	Ministry of Rural Resources and Water Development
MLARR	Ministry of Lands Agriculture and Rural Resettlement
MSSS	Management Support Subsystem
NSD	Night Storage Dam
O&M	Operation and Maintenance
RIS	Relative Irrigation Supply
SISP	Small Irrigation Support Programme
SSM	Soft Systems Methodology
WB	Water bailiff
WDSS	Water Delivery Subsystem
WDP	Water delivery Performance
ZESA	Zimbabwe Electricity Supply Authority
ZIMWESI	Zimbabwe Programme on Women Studies, Sociology, extension and Irrigation
ZINWA	Zimbabwe National Water Authority
ZITC	Zimbabwe Irrigation Testing Centre

PREFACE

It is very difficult to start this section for fear of impressing some normative priority value to the chronology of events. But I am obliged to start somewhere. I would like to start by thanking the Netherlands government for making funds available under their Netherlands Organization for International Co-operation in Higher Education (NUFFIC) for the second phase of the Zimbabwe Programme on Women Studies, Extension, Sociology and Irrigation (ZIMWESI 11). The programme co-ordinators and members Eng. Chiuswa, Dr Senzanje, Mr Mudimu, Mr Hukutangwi and others played a crucial role in my initial selection for study. I am grateful to Dr. Makadho the former Director of Agritex, his directorate and all his staff for the confidence he showed in short listing me for the study.

Mr. Willem Genet and his wife made my initial stay in the Netherlands both comfortable and hospitable and I give them special thanks and wish them well. During proposal writing in period in the Netherlands I had discussions with colleagues like Daniel Prieto, the now Dr. Jeroen Vos, Mai Shambare and the now Dr. Esha Shah who made valuable contributions and provided important criticism to my initial thoughts.

Fieldwork proved to be the most interesting and taxing part of this study as a sandwich student. Much of the survey work and field visits were conducted during weekends and holidays. I would like to thank Mr. Chitsiko my former head of division for allowing me time to slip away on Thursdays and reappear on Tuesdays. Farmers in all schemes directly recorded data pertaining to their water application practices. Water bailiffs and extension workers recorded flow data at Deure, Chakowa, Mpudzi and Mutema. I would like to thank all these farmers, water bailiffs and extension workers for their patience, enthusiasm and confidence they placed in the study programme.

Special recognition goes to elected farmer water bailiffs and group leaders Musikavanhu and farmers at Mpudzi for their meticulous recording of daily practice. I want to thank all farmers and their committees and representatives on the study schemes and others that got subjected to interviews questioning and re-confirmations for their support. Agritex irrigation engineers, extension workers and officers all provided logistical support, responded to interviews, gathered data, reviewed written materials and made comments during the fieldwork and writing phases of this thesis, deserve special thanks. I want to thank DWD (now ZINWA) and Agritex provincial heads and all their staff for their valuable support and information during the study period. My feeling is that the manuscript is our joint effort from farmers, government officials and all those who contributed.

Throughout the field study period Mr. Zhakata was always available. I cannot isolate a stage were he was not involved whether I was there or not. I have no words to thank him "*handina mazwi ekutenda*". Ian Samakande stayed at Chakowa as an undergraduate research assistant and that sparked a long time friendship. Mugutso provided valuable information on Mpudzi. I want to mention the Mutiro, Dhavhu, Maina, Berejena, Chitima, Kombora, Sibiya, Maisiri for their support throughout the study program. Elias Machingambi and Godfrey Jackson Mungoni stayed at Mutema and Musikavanhu as research assistants and later helped to compile and make sense out of the numerous plot level data many thanks. I am grateful to Mai Zinyemba for typing the first set of finding for this study. I want to thank Mr Hakutangwi, Mai Chibaro, Mai Chimbira and Dr Nehanda and for the encouragement. Dr Manzungu, thank you for the prudent financial management. I am grateful to Dr Senzanje for always providing the shelter, cover, a sounding board and encouragement as the study rocked along with the changes in the working environment.

I want to thank the now Drs. Robina Wahaj, Jeroen Vos, Puspa Khanal, Vishal Narain, and Esha Shah, and Drs-to-be Conrade Zawe, Margreet Zwarteveen, Alex Bolding for chats and discussions during the long writing process. It is even longer for sandwich programmes

due the open environment. Supervising then becomes an art. I want to consider my supervisor's art as that of hatching. Prof. Linden Vincent was able to nurture me from a hardcore practitioner interested in putting things on the ground "*kusungira migero*" through various stages of analytical debate and development to the final chapters of this thesis. I would like to express my appreciation for her patience, guidance and understanding. I also thank Dr. Aidan Senzanje for his advice and insights, and students of the University of Zimbabwe who worked with verve in several of the fieldsites. I give a special thank you to Gerda de Fauw for her practical help in the last stages of thesis compilation and organizing my visits to Wageningen.

The final parts of this thesis were completed in Ministry of Rural Resources and Water Development where the words "*You know my position as regards these things (human development)*" from the permanent secretary Mr Simon Pazvakavambwa enabled me to calmly put the final thesis together. I want to thank the Head of Ministry, my new Director Mr V Choga and all staff members for providing me with a homely environment at short notice. T want to thank the Director of Irrigation for providing company at the Kurima offices in the numerous nights I spend trying to put together the final chapters. Thanks to the new irrigation branch staff for their patience and allowing me to monopolies the use of one of our only two computers. I also want to express my gratitude to Minister Mrs. J. Mujuru and the Deputy Minister Mr. T. Rusere for providing a family working environment.

During this study many changes took place in the family. I want to thank all my family members for keeping together and allowing me to continue struggling through the study. I dedicate the thesis to my mother Marian, my brothers *mukoma* Gift Isiah and *mukoma* and *shamwari* John (Jotso) Musiyiwa who never lived to see me complete this work.

Eric Eria Chidenga

1. PROBLEM DEFINITION AND RESEARCH DESIGN

1.1. PROBLEM CONTEXT AND RESEARCH OBJECTIVES

Smallholder irrigation in Zimbabwe today is recognised to have a series of challenges of sustainability, in its profitability and management capacity. While many problems have been described, a framework is still lacking to analyse why a high level of state involvement and external funding has failed to create sustainable schemes and also provide a basis for new reflection and action to restore viability. One concept fundamental to such an initiative is "terotechnology", or the capacity to care for a scheme. This concept is linked with an effective strategy for the operation and maintenance (O&M) of systems. It is also linked to conscious thinking about design of a technological system, and its management so that the infrastructure is cared for through O&M. Conscious "terotechnology" may have existed in Zimbabwe in the past, but changes in public agency in smallholder irrigation have disrupted this.

"Terotechnology" is a critical aspect in the conscious development of an irrigation-engineering paradigm in a cadre of professionals. It underpins a set of "engineering precepts" that consciously focus on relevant technology and management choices that can create well-functioning and sustainable irrigation systems. The precepts, or codes of action, in use are indicators of both the real concern for operability of systems, and capacity to act on minor and major disruption of systems, but also of forms of control in place to make systems work. That terotechnology can work in some locations when thought through is evident: that it often collapses and corrupts under political and financial pressure is also evident.

Until now, there has been no study of the different approaches of the state in Zimbabwe in organising this 'technological care' in operation and maintenance, under different technology choices and different management regimes. Manzungu (1999) characterised the evolution of smallholder irrigation development ideas as "domineering" rather than "engineering", alluding to the dominance of preferred choices of designers rather a conscious recognition of design for a locality.

This thesis contributes to the objective of improved understanding of design choices in Zimbabwe, and of how irrigation technology and management are linked together and must be studied together with the local people to also design appropriate technological care. This, it is hoped, will contribute to better design in the future, and to informed choice of infrastructure which fits with the society that must manage it. There is a need to reflect on its engineering precepts, to see how they may restore a capacity to create schemes that can survive under the changing conditions of Zimbabwe.

Debates on problems of smallholder irrigation in Zimbabwe, and sub-Saharan Africa more generally, have alluded to many faults in the expectations on livelihood transformation and in design of management approaches in new systems. Yet very few have looked systematically either at the choices of technology made by designers for mobilising, conveying and applying water, or at the different requirements they have in operation and maintenance. In Zimbabwe, choices for water mobilisation have shifted through simple run-of-river systems to lift systems on unregulated rivers and aquifers, and later regulated rivers. There has been experimentation with layouts of sectors to be supplied with water, with or without in-system storage. Combined with these there have been both open and pressurised conveyance systems supplying both gravity and overhead field application methods.

However, alongside these interests in technical innovation, has gone a decrease in operation and maintenance support. At independence the government lost a lot of senior, mainly white, irrigation specialists to the private sector and South Africa. In order to promote black empowerment on the smallholder schemes, experienced subordinates or counterparts replaced the white managers. These were soon assimilated into Agritex structures, and were eventually rationalised under new extension structures and management. Personnel numbers and resources have been cut drastically, with assumptions that irrigators and water user organisations can replace them. This has led to loss of the unique terotechnology function of management - that is minimisation of irrigation infrastructure costs by taking appropriate care through planned maintenance, repair and replacement. Designers are currently at a loss as to what management systems to anticipate. In Zimbabwe, there are many technological permutations in use for delivering water, with as yet no systematic study that shows their different management needs and challenges, to inform future design choices.

Available studies of the smallholder irrigation sector in Zimbabwe have concentrated on management and practice of field operations, and the economics of crop production under specific conditions. The question of design appropriateness for smallholder farmers and their environment has often not been addressed locally. Irrigation design practitioners concentrate on optimising perceived engineering standards or goals adopted from professional institutions. There is a tendency to try to attain optimum distribution and application performance as given by recognised performance indicators like efficiency and equity. Delivery reliability and security attributed to technology are not given priority. There is, in particular, no documented experience on the sustainability of overhead irrigation systems across generations of users. It is therefore necessary to critically monitor their performance as a way of trying to predict their sustainability. It is also important to compare the designed, 'anticipated' outputs against the actual outputs and also understand how the water demands, and income generated are shaped by or shape operation and maintenance. The need to involve smallholder farmers in management of irrigation has increased in Zimbabwe. This has been necessitated by the requirement of the current government to reduce public sector involvement in activities that can be done by private sector or the irrigators themselves, on the assumption that this will improve performance. Irrigation management transfer (IMT) has been prescribed as one the best options of improving smallholder irrigation schemes performance (Vermillion and Sagardoy 1999), yet there is very little public documentation of schemes with successful management transfer. Attempts have been made to develop new schemes under farmer management: but there is little understanding of the details of everyday management required for different technologies. This thesis also tries to fill this gap.

This is also an appropriate time for such a study, as there is now some acknowledgement of the level of irrigation system decay in internal government correspondence and expert observations (Agritex, 2001: Savva, 2000; Zawe, 2000). There is now clear evidence of farmers failing to pay energy, repair and maintenance costs especially on pumped sprinkler schemes. The situation on gravity surface schemes is no better with little if any meaningful routine maintenance work. There has been a deliberate reduction in government staff responsible for O&M at schemes, and irrigation management committees have been formed and are expected to take over management with reduced funding from government.

At the start of this research, I was head of the irrigation branch in Agritex: I was also part of the interdisciplinary team that formulated the IFAD (1997) report on smallholder irrigation support program. It highlighted the situation of the smallholder irrigation sector in Zimbabwe. The poor performance at household level and problems in operation and maintenance were identified as areas that needed improvement. The report findings identified the following causes of sub-optimal performance:

> *"poor sustainability due to inappropriate scheme management and inadequate quantity and quality of investment; low productivity as a result of poor farmer practices, insufficient water availability and low cropping intensities and poor market access, a consequence of market information and knowledge as well as inadequate communication infrastructure"* (IFAD 1997 cited in Manzungu 1999, pp3-4).

Sources reported that this report incensed some high-ranking government officials during a stakeholder briefing session, such that some left the meeting unceremoniously. However three years later a department put together a position paper acknowledging evidence of scheme decay (Agritex 2001). My own appreciation of the poor level of care that was being given to irrigation artefacts, poor support to farmers and users, as well as the gap that existed between the concerns of designers and users, increased significantly during the research period.

Nevertheless, the design and execution of this study has been challenging, not least because of my previous position. In the selection of irrigation systems that show the technological repertoires of design in Zimbabwe, I have been working on systems in which I was also involved in design and execution. Farmers knew me, and often expected me to help in the problems documented: local irrigation workers and officials also knew me. However, I continued, as I believed that I brought important internal knowledge on the design of these systems. Also that work with research assistants and farmer representatives could provide information that might not be given to me directly as a senior officer. The information presented in this study is, it is hoped, powerful enough to meet the objectives of the study, even if further information could be made available.

In unpacking the history of design choices, I also had to research the actions of fellow officers. This proved difficult where technology choices were proving unsustainable. If Zimbabwe had a culture of debate on design outcomes, as has been documented in some countries in the past (van Halsema, 2002), this discussion might have been straightforward. However I was forced to move twice within government institutions during the write-up of this thesis due to differences in opinion over the realities and best approaches to smallholder irrigation development. Nevertheless, it seems now that a culture of debate and questioning is slowly creeping in to members of the irrigation fraternity, perhaps partly as a result of the findings of these studies. A senior politician and cabinet minister recently acknowledged that smallholder irrigation development could have been done differently since independence[1].

1.2 SMALLHOLDER IRRIGATION IN AFRICA AND ZIMBABWE: DEBATES ABOUT DESIGN AND MANAGEMENT

Moris (1987) described irrigation as a ‘privileged solution’ in Africa, because of the way a central concern over drought and resultant food insecurity as a “privileged problem” made African governments pursue irrigation without clear attention to the costs, livelihood options and management problems that may arise. As a result, irrigation schemes are implemented immediately funds become available, with irrigation viewed as a means for modernising agricultural production, minimising food imports, removing food deficits and ameliorating the

[1] "This is an exciting time and we are on the threshold of making a breakthrough in a development which has eluded us for the past 22 years,….over the years , we have been refusing to think. The good lord gave us the rivers, good soils and the manpower but we have been failing to utilise them, God must be laughing at us saying such people, little people, they have everything but they cannot use what they have…." Cde Mudenge, The Herald 25 -06-2002.

effects of droughts (Moris 1987, pp1; Manzungu 1999, pp30)[2]. This often entails that large financial and material resources are mobilised locally and supplemented with substantially more foreign assistance. This foreign support, whether bilateral and multilateral, normally includes technical assistance programs to help with project identification, planning, design and in some cases management. This often results in the pursuit of designs linked to foreign experience rather than local needs (Manzungu 1999, pp 133).

Moris highlighted several problems arising from this pursuit of irrigation without clear local reference. Moris recommended that policy makers in Sub-Saharan Africa consider the following issues:

- the security and adequacy of water supply
- crop returns and labour demands
- understand and recognise farmers strategies for food security
- land tenure issues to reinforce farmer empowerment
- practical site management possibilities and problems need to be understood.

This thesis picks up these issues as a first focus on the study of inappropriate irrigation design choices.

Tiffen (1987) made a wider survey of socio-economic and institutional problem areas in irrigation identified by irrigation professionals, which also highlighted these and other problems for the sub-Saharan region, shown in Table 1.1. Over 50% of respondents identified problems in agricultural marketing and other services, labour, tenure and conflicts and different aims between the state and farmers. However, they also identified unclear responsibilities and poor provision of maintenance and water delivery, and poor staffing conditions as major problems. Maintenance is considered to be one of the biggest stumbling blocks to irrigation development in Africa (Ubels and Horst 1993). The issue of creating corporate identity, accountability on a non-kinship basis, finance creation, and caring for collective equipment have proved to be a problematic in Africa (Speelman, 1990). While this study recognised all these problems in Zimbabwe, it looks in much greater depth at these issues of responsibilities in water delivery and maintenance, and at staffing and skill questions, as core issues for terotechnology and better management of irrigation.

Moris and others have gone on to work further with the first and last points of his list, on water supply concerns, and on the management problems emerging in small-scale irrigation. Water supply is critical not only for the way it affects security and adequacy, but also through the way the water source shapes operation and maintenance needs. Water supplies in humid areas are generally more secure and reliable. Humid areas being zones where rainfall generally exceeds CWR over the crop-growing period as occurs in natural region 1 and parts of natural region two in Zimbabwe. Generally most of the irrigation in Africa is in arid and semi-arid zones and its water supply is characterised by highly variable seasonal and annual river flows. In periods of high river flow these systems face problems of flooding that require technical, material and financial resources beyond the capacity of the local communities to both mobilise and sustain. Rivers may also have low or zero flows in dry periods, requiring substantial investment for flow stabilisation. Governments are therefore forced or called in to marshal these financial resources, and in the process gain significant control over scheme management (Greenland and Murray-Rust, 1988).

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[2] Cde Mudenge continued to outline the solution typically as detailed by Moris "We have seen our problem and we are going to put those 100000 hectares under irrigation and feed the nation at an average of three million tonnes per year…. We had droughts in 1972, in 1982, in 1992 and in 2002 and we cannot fail to see that the only avenue or national food insurance is to embark on massive irrigation. Everyone must be prepared to go and work in the clearing of the land and immediate planting of the maize in that area as soon as the Government approves our application" The Zimbabwe Herald of 25 June 2002.

Relating to the management environment, Moris rightly points out that western donors have been neither sympathetic nor cognisant of the particular managerial problems in African parastatals: to this I would add other local development institutions too (Moris 1987). Agencies operate under pressures related to internal politics including ethnicity, and corruption, which include problems of adding unnecessary staff, and competition to offer superior fringe benefits. This 'management gap' in terms of inappropriate models of control and inadequate skills is partly related with the training practice in overseas institutions. These equate irrigation management only to hydraulic management at the perimeter and on-farm water management at field level. They fail to emphasise the sustainability aspect that depends on the management's ability to support an introduced technology, in which ensuring water (supply) is only one of several aspects. Other relevant management aspects include: input supplies, maintaining equipment, obtaining cost recovery, controlling disease outbreaks, extension services, procuring foreign currency for spares, monitoring operations and maintenance (O&M), credit facilities, marketing arrangements, setting performance standards, and irrigation scheduling. "*At issue is not what the water engineers recommend, but rather the critical topics they ignore*" (Moris 1987, pp118-119).

Several authors have gone on to list causes of failure, often overlooked by these bureaucratically imposed schemes, which lead to a wide gap between the actual performance and the government objectives. These include:

- the intensive bureaucratic control in smallscale irrigation schemes, which is not conducive to the quasi-industrial character of schemes in marginal environments with no import facilities (for repairs) and high risk for specialised production due to lack of markets (Moris, 1987)[3].
- officially reported costing of projects which are incorrect with a lot of costs left out (deliberately or otherwise) but eventually giving high (but in most cases false) economic internal rate of return (EIRR) in the appraisal reports (Tiffen 1987; Moris 1987; Speelman 1990)[4].
- The tendency by irrigation authorities to impose crops or cropping patterns which farmers either do not like or are not able to sustain (Manzungu, 1999, Speelman, 1990):
- 'blind faith' in sophisticated technology in an unsuitable environment (Ubels and Horst 1993; Speelman 1990)[5].

Debates about technology choices are less common than the critiques of poor understanding of local conditions, but they are increasing and have at times been confused by terminology. Moris (1987) used the term 'modern' irrigation to refer to any formal irrigation scheme planned and implemented by the government that is not 'traditional'. Traditional irrigated cultivation is often considered inconsequential (Manzungu 1999, pp30 - citing Diemer and Vincent, 1992:143; Underhill, 1990: 14; Adams, 1992). Cornish (1998) refers to use of piped and pressurised systems as modern irrigation. Horst (1998) sees modern irrigation as the use of modern ideas to solve modern problems.

[3] Industrial denotes the tendency towards growing uniform crops for the market which maybe external on large scale using the same irrigation technology often with components that are externally sourced. This is in contrast with livelihood food production associated with tradition simple systems especially in isolated hill country.

[4] An evaluation done at Wageningen on eleven EDF funded African projects all with initial EIRR higher than 10% found that on recalculation four of the projects actually had negative EIRR with only one exceeding 10%.Tiffen observed similar tendencies in 50 World Bank projects owing to what she called "manipulation and genuine difficulties of predicting scheme outcomes".

[5] This has been attributed to the engineering paradigms of donors and external experts and the failure to reflect on models for Zimbabwe

Table 1.1.1 ODI survey on the causes of problems in irrigation, by region (source Tiffen 1987) (figures give percentage of respondents noting these problems)

Group	Local Economics				Socio-Political				Institutional/Planning					Implem entation		Unpr edict able
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Asia	23	40	20	23	23	30	10	70	33	40	54	27	30	17	13	17
N Africa and Mid-East	17	33	17	17	67	0	0	17	50	33	50	83	17	33	0	17
Sub-Saharan Africa	48	**83**	17	**50**	**58**	33	**50**	25	33	**50**	33	**58**	33	16	8	33
Latin America	0	10 0	40	0	40	0	40	0	20	0	80	0	40	0	0	0
Total	25	49	21	26	38	26	23	43	34	38	49	34	30	17	9	19

Key to table 1.2.1

A. Existing, non-project activities of intended beneficiaries

B*. Agricultural marketing factors(prices and price policy; risk in purchasing inputs or main staple food; crop patterns at variance with market requirements; availability or quality of inputs including repair services and credit; poor communications infrastructure)

C. Natural resources use and conflicts (ground-water management conflicts; water –use outside project area; conflicting hydro electric power requirements; conflict with livestock owners over land use)

D*. Labour (peak labour shortages, appropriate farm size and employment effects).

E*. Land tenure, consolidation, compensation, resettlement

F. Equity issues (income, power and wealth distribution and conflicts; disadvantages for women)

G.** Conflicts between state and farmer aims and other political constraints (excepting price policy issues considered in B)

H. Farmer organizations, conflicts between farmers affecting institutional arrangements, conflicts between farmers and farmer groups and other local institutions (eg local governments etc).

I. Cost recovery, water charges

J.** Allocation of responsibility and provision of resources for maintenance and on farm development; efficiency and equity if water delivery services

K. Project concept and development assumptions; suitable technology, faulty planning mechanisms (eg. Inadequate preparatory studies, unrealistic timetable)

L.** Staff: incentives, quality ,quantity

M. Relationships of main and other national agencies involved in project.

N. Procurement and contract mechanisms

O. Lending agency role and supervision; lending agency and national government conflict; consultancy and government department conflicts.

P. Unpublished external events (unexpected inflation, extraordinary drought, civil conflicts etc).

* **issues found important in Sub-Saharan Africa, and also in this study for Zimbabwe**

** **issues found important in Zimbabwe and studied in more depth in this thesis**

Another cause of bad system development has been the lack of local capacity to plan and implement schemes designed by foreign consultants, with no facilities for learning at the local level. Schemes are implemented without feedback from farmers[6]. Governments are sometimes forced to take over schemes after the management agency fails to meet expectations and accumulates debts, as the Kenya government had to do with the Bura scheme (Moris 1987, Moris et al 1990 pp297-311). The net result is a situation where the government, external consultants, the irrigation agencies and farmers blame each other for the systematic malfunctioning widely evident in smallholder irrigation systems, without doing anything about it. One of the main objectives of this study is to provide a framework of taking such action during or after the proper problem diagnosis, to allow for a 'learning approach'. Many other authors endorse these views on inappropriate understanding of local needs and options in design and projects implementation (Manzungu, 1999; Miejers, 1992: Diemer and Vincent, 1992; Speelman, 1990). Speelman (1990) says the same problems of unrealistic planning due to completion, budget and time pressures lead to farmers' withdrawal from full participation in system planning and design.

Moris concluded by saying that irrigation should not be considered where farmers are subsistence-oriented, and working in remote areas (Moris 1987, pp118). There is a tendency to disregard the farmers' livelihood practices before irrigation and assume that the water and land were not productively used before the modern schemes (Speelman 1990, pp7). This statement is contested for Zimbabwe, as it translates to unnecessarily denying these communities access to resources, and because state programmes still pursue irrigation development in commercial zones as well as areas with poorer market options. However, the argument of this thesis is that more attention should be paid towards the identification of appropriate designs, within a learning process between engineers and communities that may eventually transform the options for local communities in irrigation.

Learning as a concept involves the ability of the difference actors to suspend their assumptions (view the world differently than experienced only) so that they can engage in a process of deeper understanding of reality. This will involve engaging in dialogue (*dia* Greek for through and *logos* Greek for word or meaning). They will also have to practice listening and develop ability to enquire and reflect (Senge 1993 238-249). This will facilitate the process of understanding dynamic complexity (that is cause-effect relationships) as opposed to only 'detail' complexity.

Studies in Zimbabwe

As Manzungu (1999) noted, studies in the smallholder subsector prior to 1990 were mainly done by socio-economists concerned with the benefits of the interventions on the livelihoods. Hunt (1958), Reynolds (1969) and Rukuni (1984) are among the most noted for Zimbabwe. A first shift to study management came through Makadho (1994) centring on the use of the dominant gated surface irrigation schemes and their performance, focused on equity and later relative water supply. He proposed some timeliness indicators that were meant to provide a quantitative measure of the deviation in meeting crop water requirements from the water delivery. He further qualified the timeliness by suggesting an adequacy measure. This work, although well documented and published in international literature, has not been used in practice in Zimbabwe. There has not been any reference to the issue of timeliness in the numerous discussions with irrigation practitioners and farmers, perhaps due to the limited

[6] "External consultants are usually based in Europe or America, and return to base after each phase in project development. This institutional setting inhibits learning from experience at the local level. By the time feedback from farmers can occur, the physical investments are locked in, and, in any event, the experts in charge of the irrigation design will have departed" (Moris 1987, pp103). Similar encounters will be discussed in the Bonde and Musikavanhu case studies in this thesis.

attention given to technical monitoring and evaluation of smallholder irrigation schemes. Hydraulics Research carried out a more diverse study of management problems and design issues at Nyanyadzi (Pearce and Armstrong 1990, Tiffen and Harland 1990). However, in design the study looked more at health issues in canal design, block planting and crop based scheduling. Studies in the early 1990s were more focused on the performance of systems, with a concern more on whether farmer-managed systems performed better than agency-managed systems, rather than on technological choices (Rukuni *et. al*. 1993).

A further shift in technological interventions came in the 1990s, as new design concepts were introduced in Zimbabwe after Makadho's studies. Two such designs are the incorporation of fayoum weirs in surface water distribution and the introduction of draghose sprinkler systems in overhead systems. Manzungu referred to the proportional division fayoum weir structures as "transplants" from Egypt by the design engineers' company (Manzungu 1999). Like proportional weirs, draghose approaches also deliver water on a continuous basis. However the water delivery recipient is shifted from the group to the individual farmer hence designing out the whole concept of using time of receiving water as an important management concept. This therefore suggests that designers were viewing improvement mainly from the structural point of view, looking only at new technology choices. Manzungu (1999), using actor network analysis on smallholder irrigation systems tried to draw attention back to field realities by way of a *"criticism of both design ideas and development interventions*" (Vincent 2002 pp 75). However, there has been no review of technology choices within the engineering community in Zimbabwe.

The starting point for both design and management interventions has been an attempt to meet the crop water requirements (CWR) based on the demands forecast from the latest version of the CROPWAT program[7]. Designers prioritise maximising individual water use efficiency and productivity as measured by return per unit of irrigated land. Makadho's (1994) management approach was based on fine-tuning the delivery to move towards the objectives of meeting the CWR. The draghose systems have placed operation and maintenance responsibility onto individual farmers first, and corporate structures as second choices. Farmers' dominant concerns have tended to focus on security of delivery, equity and ability to meet operational responsibilities Proportional systems on the other hand do not view meeting of the CWR as a primary design object. Therefore there is currently no common ground or agreed set of objectives in the various design and management interventions.

1.3 TOWARDS A THEORETICAL FRAMEWORK

Irrigation as a complex phenomena

The complex world of action in irrigation, where humans design and build systems and engage in appropriating them, has given rise to several conceptual approaches linked to understanding social and technical interactions, and the analysis of change options and decision making processes.

According to Mollinga (1998) "*a comprehensive understanding of irrigation requires a framework that integrates technical and social science perspectives"* (Mollinga 1998). He cites Uphoff (1986), who said that human physical aspects interact continuously and profoundly in irrigation and therefore make the process a sociotechnical construction. He also cites Huppert (1989) as saying that irrigation systems embrace social and technical system components and subsystems. Huppert identified attributes of sociotechnical systems, as the

[7] Halsema has referred to this new focus on crop water requirements as a "CROPWAT paradigm" thereby emphasising its general adoption without adequate attention to its suitability in specific situation (Halsema 2002, pp24).

close interrelationship between social and technical features, openness to systems environments and an emphasis on conversion processes of inputs to outputs. Mollinga argues that both Uphoff and Huppert treat the technical aspect as a "black box" *i.e.* the phenomenon is either not understood or unquestionable. There are other interdisciplinary approaches to irrigation study, such as the natural resource system approach, but according to Vincent, while it can show misfits between institutions and infrastructure it does not offer explanations and proposing action (Vincent 1997, pp42). Some even consider risks of water supply and uncertainty as externalities to investments decision on land and water (*ibid,* citing Bromley 1982)[8].

In order to undertake analysis Mollinga decided to concentrate his attention on the social dimensions of irrigation artefacts. He deliberately focused on the physical components or tools of the irrigation technology. Mollinga concentrated on 'control', and power relations at structural level. The focus enabled study of the interactions of hydraulic, organisational and political control that make a system work. However, in this approach the learning process of designers and users of artefacts at other structural power levels are not purposefully considered. It does not allow the conceptualisation of system design to be studied, nor the processes through which design and implementation create and bring a system reality into existence. Thus it also does not allow new objectives shaping technology choices and contemporary design processes – such as optimisation, modernisation and participation - to be considered[9]. Soft systems methodologies developed by Checkland (1981), with the aim of investigating complex systems involving engineering and human action are more commonly used in the study of design and management processes and their inter-relation (Nijman 1993; Scheer 1996; van Halsema 2002). Before studying these however, we need a further discussion on technology and its transformation.

On irrigation technology, and its trajectories and repertoires

Technology is said to be emergent **through systematic reflection ("*logos*")** from the responses and practice **of man's power to manipulate the physical and social world ("*techne*"**) in response to challenges posed by the environment and the needs of society (Sagasti in Baark and Svedin 1988, pp42). Technology has also been defined as *"simply a body of knowledge about techniques"* (Freeman 1974 cited in Baark and Svedin 1988, pp5) also it has been defined as *"broad area of purposeful application of contents of the physical, life and behavioural sciences"* (Jantsch cited in Baark and Svedin 1988, pp42). In Zimbabwe, too often irrigation design has been approached simply as a body of techniques or stylised application of certain knowledge sets. It is the systematic reflection that is pursued in this thesis.

[8] Makadho used this approach to study schemes in Zimbabwe and produced some statistical indicators on timeliness of irrigation. However the methodology failed to uncover some key institutional and infrastructural issues that this study unravels. Manzungu (1999) and this study actually find extension staff be part of the problematic being actors or management system support agents that also require understanding. A typical case is Manzungu's deduction that water shortage is due to poor managerial ability in Agritex schemes, and therefore management is the central issue for all schemes.

[9] This structural weakness became evident in the implementation of the Smallholder Irrigation Support Programme (SISP) that was formulated in 1997 (IFAD). The programme had been designed to run in parallel an institutional and technical development program. At implementation the technical program spearheaded by government fell behind resulting in a gap and focus on water management without a technological complement. Several changes in personnel and institutional set-up have not succeeded in treating the management issue in a co-ordinated way.

Dosi (1982) also notes how technology includes the perception of a limited set of technological alternatives and notional future developments. A technological paradigm embodies strong prescriptions on the direction of technological change to pursue and those to neglect, with a ‘technological trajectory' as the pattern of ‘normal’ problem solving activity on the grounds of this paradigm. Technological paradigms have a powerful exclusion effect: the efforts and imagination of engineers and the organisations they work for are focused in rather precise directions while they are, so to speak. ‘blind’ to other technological possibilities. This thesis will investigate how smallholder irrigation technology has seen a trajectory of irrigation technology from simple gravity distribution methods to pump-lift and pressurised overhead sprinkler systems, in a paradigm linked particularly to control and efficiency, in both technical and institutional terms. What has not been thought about enough is how to design technology and management together, so that both are viable in given local contexts and they work together, to provide the water supply and technological care necessary to keep an irrigation system working.

Van Halsema (2002) developed the notion of the ‘irrigation concept’ used in design, to study the objectives given for irrigation delivery, and the understanding of appropriate infrastructure and management systems that could work together to reach this objective. It is the changes in these ‘irrigation concepts’ in Zimbabwe, and the forces driving them, that is a key theme of this thesis

The functioning of technology has been explored through a number of approaches. Mollinga described technology as artefacts with a use requirement (Mollinga 1998). He reserved the term technology to the hardware component of irrigation on the understanding that the knowledge and human labour power would *“automatically come in focus when artefacts are studied in context”* (Mollinga, 1998 pp13). Vos (2000 pp16) has studied technology as hardware (artefacts) and software (knowledge, skills, organisation and information) citing Mollinga *et al* (1987). However there is a growing call for the inclusion of environment and ergonomic aspects. Vincent has defined technology as existing at the interface of resources and society, being the capacity to transform resources into desired things (Parajuli 1999, pp9). Stewart’s definition, that Parajuli considers helpful in identifying the necessities for an output, defines technology as *“ a complex of goods, products, processes and organisations which make good and efficient use of the means available to achieve… objectives”* (*ibid.).*

Mollinga’s view leads to a close study of social domain of artefacts, social construction, social requirements of use and social effects. Vincent's definition leads to a wider appreciation of the breadth of coverage of design, the way a problem is perceived and a solution developed within the innovative capacities of society. It also allows for a closer study of the effect of knowledge of the resource base (that include society’s capacity to facitate resource use) in shaping irrigation design and operation (Kloezen 2002; Parajuli 1999; Knegt and Vincent 2001). Both inform this study.

The developing world is caught up in a spiral of consumerism of technology (including irrigation) and thought processes (science) that is developed in the first world. The main contact is the western engineer whose role is to adapt the technology in the way he/she perceives is relevant to the recipient community. Most of the time the foreign expert uses a technological trajectory, that is the actual problem solving activity, that is based on a western problem situation (Sagasti in Baark and Svedin 1988, pp38). The result is that the necessary scientific understanding of the appropriate technological base is missing, and there is no cultural understanding or appreciation, leading to problems of sustainability (Speelman 1990).

Such technological trajectories are normally not based on the demand-pull of the market (or the preferences of local people) but more aligned to the technology-push effect of hierarchies. At scheme level, communities can simply develop or form defensive images and technological animism[10], when faced with technological management and sustainability issues that evade their control, "resourcing" capacity and rationality (Wynne in Baark and Svedin 1988, pp4, 80-101). There seems to be no possibility for emancipation unless there is internalisation, organic and endogenous scientific and technological growth processes (Speelman, 1990; Sagasti in Baark and Svedin 1988 pp38; van Halsema 2002). This is what we must hope for in Zimbabwe.

The technological trajectory in Zimbabwe can be summarised as a progressive shift from run-of-river gravity canal surface systems that were developed in Manicaland from 1912 to 1950. A need to expand irrigation to flatter areas in the middle Save valley with limited gravity head lead to introduction of lift schemes with diesel, then electric, powered pumps. These generated considerable power costs leading to a debate in the 1970s on the need to maximise area served and thus reduce field losses. The first consensus was to line distribution then field canals in that order. Another debate proposed pressurised distribution and sprinkler application. A number of trials were done but only one large scheme endured for 30 years. With the advent of independence pressurised irrigation system development got technical support from FAO. Implementation started with rehabilitation of former commercial farm systems and then spread to new small schemes of size ranging from 10 to 20ha with mainly draghose systems from 1988. These were popularised and started being scaled up to over 100ha in the late 1990s. Technological change at this stage was hardly accompanied by any debate, leaving a range of irrigation systems designs in a technological repertoire largely unquestioned since independence. The net result has been a number of schemes were developed now showing operation and maintenance stress. The problematic is what and how appropriate is the management support required to sustain the technology selected. The objective of the technological change has also not been revisited.

However, in Zimbabwe, the changes in technology choices have been driven by the extension of irrigation development into new environments and new options from water development, rather than just new technologies *per se*. For this reason, a sub-theme of this thesis is to look at the work of innovation in changing design choices in Zimbabwe. A desire to keep within the global stream of modernisation has had a directing effect on the search for innovation. Leeuwis (2002) builds on the view of Roep (2000) to propose that an innovation needs to be understood as a 'new working whole': it may be a new way of doing things, but it can only be considered an innovation if it works. This view is both practical to use in field study, and avoids the prescriptive of economic or technical efficiencies, or participatory rhetoric, of many other definitions of innovation, and the reforms, restructuring and modernisation done in their name. Rather it leads immediately to the questions of: works for whom and according to which/whose principles? These are issues that should be debated out between those using, managing, working in and paying for different irrigation systems. It also leads to wider questions of how to guide innovation, both in design of new ideas and processes, and use of different actors for engineering transformation. It allows understanding of outcomes when programmes to steer innovation act incompletely or in the wrong part of a complex institution.

Leeuwis makes a distinction between 'regular' innovation – something that does not give fundamental challenges to prevailing relations and requires 'single loop' learning – and 'architectural innovations' requiring a fundamental reorganisation of social relationships, technical principles and rules. With good communication perhaps architectural reorganisation can be made workable through platforms of stakeholder negotiation.

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[10] This is the practice of attributing phenomena to acts of God and thereby resorting to rituals and myths.

This paper shows that such communication, however, remains rare in Zimbabwe. Leeuwis also talked about five problem fields to which innovation is 'expected' to respond, that is change in: the social environment; perceptions of reality; human aspirations; social and technical opportunities, and natural/physical circumstances. This study will return to the influence of these problem fields in driving changes in technology choices in the conclusions. Making irrigation systems work requires thought and experience about technology, which includes both artefacts, and the skills necessary to operate and organise production. These skills and organisation include operation and maintenance (O&M): making things work includes the work of technological care also called teretechnology.

System perspectives for studying the evolution of irrigation systems

The consensus that smallholder irrigation schemes are complex underscores the problematic that arises methodologically in trying to analyse them from a conceptual and technical point of view. Checkland's description of the soft systems methodology (SSM) for analysing systems as something containing both seems appealing[11].

Checkland (1981) classified five forms of systems, that are natural, designed physical, designed abstract, human activity and transcendental systems[12]. Van Halsema (2002) identified irrigation systems as designed physical systems that were also 'open systems' in the way they were also shaped by their social environment and vice versa (Halsema 2002, pp 14-15, Vincent 1997, pp41). While often irrigation systems are designed as if they are closed 'hard' systems operating to commands, one designs like this at one's peril, because activities like scheduling and distribution will always be contested and negotiated by waters users and operators. The simple "hard " reducible systems can be engineered to give single value solutions related to efficiency and effectiveness. Modern industrial and process problems use the concept of 'performance' to test operations and find satisfactory solutions. However, for open social systems, the solutions will come from perceptions of satisfaction as well as possibilities for action. The critical elements for adoption of solutions include clearly defined users and owners, and consideration of environmental constraints. The SSM approach thus facilitates purposeful enquiry into smallholder irrigation practice with a focus on the design, operation and maintenance practices as root problem areas.

It allows enquiry to take place simultaneously for:

(a) The logical stream of analysis which deals with the relationships between the water resources availability, land irrigability, availability of construction materials, and finance for development or upgrading, as well as the expertise to deal with the engineering of well specified outputs.
(b) The stream of cultural analysis dealing with analysis of the intervention and social system analysis, that is of particular importance to smallholders dominated by "unskilled" labour endowments with their strong norms, myths and values that make them particularly vulnerable to power pressures such as political, economic, social and others.

Another major advantage of SSM is that, unlike some sociological methodologies such as the actor oriented approach that have been used exclusively by some researchers in Zimbabwe, SSM allows inquiry to be done by insiders. Thus the researcher can be a direct participant in

[11] "A methodology will lack the precision of a technique but will be a firmer guide to action than a philosophy. Where a technique tells you 'how' and a philosophy tells you 'what', a methodology will contain elements of both 'what' and 'how'." (Checkland 1981,162p)

[12] Other systems classifications have been done by various systems thinkers, notable ones being Boulding's informal intuitive hierarchy of real-world complexity and Jordan's dimension-based taxonomy of systems (Checkland 1981,105-108)

the smallholder development discourse[13]. In practice insider researchers can also adopt actor-orientated approaches when they become direct participants in the course of research work as highlighted at Chakowa in chapter 3[14].

Systems concepts in real irrigation life

The underlying problem in real-life irrigation and its engineering is that *"the leverage in most real-life systems, such as most organisations, is not obvious to most of the actors in those systems. They don't see the "structures" underlying their actions"* (Senge 1981, pp114 emphasis in the original). But Checkland also highlights that *"...the engineer's problem is a structural one: there is a gap to be bridged between the future state and the present state; how to bridge the gap is the problem"* (Halsema citing Checkland 1981, pp139 emphasis in the original). It is therefore possible for engineers to fail to see the social structures that can work in real life irrigation situations. The ability of appreciating these possible structures lies at the core of **engineering precepts**. This is the deep understanding of science, technology environment, social, economic and other issues that are required to enable a cadre to obtain enduring solutions to problematic situations using engineering knowledge and principles.

For understanding outcomes and debating change, SSM also identifies four principles that can be acting in systems that can be interpreted for irrigation, which are of time-independence, structure-based directiveness, equifinality and true finality or purposiveness (Halsema 2002, pp11 citing Bertalanffy 1968, pp78-79).

Physical systems are usually in a state of evolution towards a final state: however, actions can be taken that direct and maintain a system in a particular time-independent state. Directiveness based on structure involves striving for an arrangement of structures that leads the process in a particular way. Equifinality is the condition that the same final state can be reached from different initial conditions and in different ways (as open systems progress towards a steady state). There is normally failure to recognise that changing initial conditions may not always give the expected final state. Thus finality or purposiveness means that belief and acceptance of the goal actually shapes behaviour. Typically low technology farmer-managed irrigation schemes (FMIS) with reliable water supply attain time independent conditions if no external competition is imposed. The outcome of the typical technology-push down common in smallholder irrigation systems is dependent on the organisational structures that prevail.

The core study of both performance outcomes and process in SSM also helps to define the approach of this thesis. To explore the performance of a scheme, we also have to understand the management or control processes put into the system for particular end goals. The elaboration of tasks, mobilisation of materials human and financial resources required for the operation and maintenance (O&M) of such a state is the responsibility of scheme management. This management can be users, or locally hired or contracted. The performance of both the system water delivery and its O&M can be elaborated, monitored and evaluated against standards within a range predetermined and confirmed at the design and

[13] Manzungu (1999), Magadlela (2000), Vijfhuizen (1998) all used the actor-oriented approach. Other researchers like Rukuni (1984) and Reynolds (1969) were also outsiders. The irony is of course that, due to my transfer just after completing fieldwork, I wrote part of this thesis as an outsider in conformity with the norm. Leeuwis (1991) identifies this as one of the weaknesses of the SSM. The client can disown the results of the analysis. However Checkland accepts this weakness of SSM inability to handle conflict or structure society, and suggests differences be taken as new opportunities for the client and researcher to redefine another round of enquiry (Checkland 1981).

[14] This is an enriching interaction of SSM and actor orientated approaches as it reinforces the essential ownership component of research findings that can be lacking in actor-oriented approaches, but removes the subjectivity that can beleaguer the SSM at crucial moments.

implementation stage respectively. It is not normally anticipated that these processes produce radical deviations of both service delivery and O&M. The direction and actions are expected to be in orbit and within the confines of the energies (as determined by time, material, human and financial resources available) of the management.

The SSM methodology thus also highlights how evolution comes through decision-making and can come without major structural changes. As Nijman (1993) writes*: "decision making is considered the major force determining the performance of irrigation systems. ...management is therefore in terms of processes rather than in terms of structures and organisational units (such as top management, a division, a department etc.*)" (Nijman 1993 pp20)

The recognised management dimensions are; human resources; provision of information; financial control systems; provision of knowledge; organisational or institutional roles and rules, and structure[15]. The lack of detailed attention to these abstract management processes account for many of the failures in crop based water delivery and failure to attain the anticipated efficacy and efficiency targets. This is due to the shortfalls in "monitoring, information processing, and structural target management that require more skills and change of operation staff and water users than is usually acknowledged" (Halsema 2002, pp14; Nyamugafata in Manzungu 2000, pp55).

Thus three processes are identified for study in this analytical framework:

1. the physical movement and availability of water which require action and decisions such as gate control (operational control);
2. decision making and control of processes such as water allocation and decision making and control of the management conditions (process control) and
3. decision making processes or management control which is the highest level of strategic management (policy decisions).

This leads to a framework of analysis of:

⇒ Hydraulic/technical control in the Water Delivery Subsystem (WDSS),
⇒ Organisational control in the Management Support Subsystem (MSSS) and
⇒ Socio-political control as actions taken in leverage of WDSS and MSSS[16].

In practice as both technical control (WDSS) and organisational control (MSSS) change in time and space, water delivery is an emergent property. The outcomes of these processes are studied through water performance criteria, discussed in section 1.5, and by study of the actions of water users.

1.4 A FRAMEWORK TO STUDY DESIGN-TECHNOLOGY-MANAGEMENT INTERACTIONS

Two basic sub-systems are thus conceptualised from a practical functional and operational point of view for each irrigation system. These are the water delivery subsystem (WDSS) and the management support subsystem (MSSS). This is very similar to the dual system approach proposed by Kelly (1983). A WDSS is divided into system components that closely resemble

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[15] An institution is taken here to mean any forms of agreed practice in human interaction and transaction while an organisation is the recognised or agreed form of a structure or institution or groupings.

[16] Mollinga refers them to as the three dimensions of water control that is water control (technical), water control (organisational) and water control (socio-economic and political) (Mollinga 1998, pp25-27).

Kelly's concept of four phases in irrigation that is; the water source control (mobilisation, that is abstraction and conveyance); the water delivery (distribution); the water use (water application) and the drainage. The management support subsystem was recognised but not prescribed, coinciding with Kelly's preference to discuss roles and rules rather than specific structures in management. He, like Hunt and Vincent preferred that formal management organisations emerge from a range of social forces and technical needs and should not be prescribed (Hunt 1989, Vincent 1997 pp39)[17]. The MSSS is developed here to encompass the range of collective action, organisations and services that can leverage, and counter-balance and control the water distribution sub-system into working well. The WDSS and MSSS both include control actions and decision making elements – technical and institutional – that must act together in manipulating the system to give the desired water delivery service.

The Water Delivery Subsystem (WDSS)
This comprises the basic water allocation i.e. water right/permit, abstraction/diversion/storage structure, conveyance, distribution, application and drainage components The important aspect to note here is that these elements should form a continuum for water delivery at any one time. Water moves from the hydrological catchment and is stored and or mobilised into the conveyance components. The water continuum is broken by important interfaces that represent structural discontinuities with different interests and are centres of negotiation (Manzungu, 1999). One such interface is that between the hydrologic and water delivery subsystem. Here the interests of irrigators and those of other consumers like domestic water, other right holders and the environment interact. A drainage component can be incorporated where relevant, but it is not a focus of this study.

System components can be classified in relation to the skills, resources and manpower needed to operate and maintain them. 'Simple' system components can comprise a flow right or allocation in a specified catchment, a simple gravity run-of-the-river diversion structure, an earthen canal and simple earthen diversions of water thereof to flood irrigation lands. 'Sophisticated' system components may comprise a storage right and reservoir in a specified catchment, river pumping into piped distribution networks and precision individual pressurised application emitters. In between these systems are a variety of combinations of artefacts that are at disposal of the enterprising designer. This is in line with Kelly's notion that the organisation of irrigation is based on the performance of tasks in the four phases. The dominant, but not limiting, tasks being construction of irrigation facilities, operation and maintenance, allocation of water and resolution of conflicts. The importance of the different tasks varies with the setting, which can only be determined empirically (Kelly 1983, pp882).

The Management Support Subsystem (MSSS)
The management support subsystem comprises all those resources that are used to control, sustain the operation, functioning and continued existence of the water delivery system[18]: the collective action, the resources and the skills for action to obtain water delivery and its desired

[17] Vincent (1997) calls for use of emergent organisational structures, referred to as clumsy institutions by Thompson (1995), in new platforms for resource management.

[18] Manzungu citing Uphoff makes a distinction between management - as being concerned with flexibility, adaptation, learning and strategies - and administration. Administration is then about following prescriptions of schedules, criteria, instructions and guidelines. In this study it is argued that management extends from the fluid activities of planning, through structuring of organisations, control and supervision. The learning process and adaptation should therefore be allowed to take place at all levels. The acceptance of the division is the root cause of the African problems of smallholder irrigation that are prescribed by power politics or authoritative bureaucracy without allowing for a homogenous learning institution, and should be discarded.

output. These components could be developed and incorporated alongside the continuum of the water delivery system in different ways. Some of the structural components include: irrigation management committees, extension services and crop production and marketing structures, health facilities and schools, environmental management structures and local government and traditional leadership as well as the service infrastructure of telecommunication, roads, and power lines[19]. The support system can have a direct or indirect effect on the ability of the water delivery to sustain its function. The MSSS are social creations. They may themselves require social action and financial resources for their operation and sustainability, in order for them to continue supporting the water delivery subsystem.

A number of individuals would like to classify some of these subsystems further into institutional, productive, environmental structures, as appropriate. This analysis does not do this, since it is not aimed at recommending a detailed framework: Like Hunt (1989) it rather looks to see how, in the case studies, different elements get used or mobilised to make the WDSS function.

Each irrigation system can be described according to the interacting subsystems considering its system design, operation and maintenance. The deliberate lack of prescription makes it possible to study the different system components according to their situational relevance and inherent complexity, and to suggest appropriate interventions. This is line with Kelly's ideas of the possibilities of centralisation and articulation of institutions at the different phases as per specific requirement (Kelly, pp883-884). It is also in keeping with the idea that its best to study irrigation as both a designed physical system and an open system, always with reference to the wider social environment[20].

Leveraging the WDSS and MSSS

The interactive process of technology and institutions is analysed by applying the concept of 'leverage', which is the "bottom line of systems thinking" as given by Peter Senge. Leverage is, *"seeing where actions and changes in structure can lead to significant, enduring improvements. Often leverage follows the principle of economy of means: where the best results come not from large- scale efforts but from small well-focused action*s" (Senge 1981, pp114).

Here it is assumed that there is a basic physical WDSS subsystem that can be defined for each smallholder irrigation system. This physical subsystem can deliver water to the community in a basic simple way as defined by crop needs or basic policy at primary level as summarised in fig 1.3. However in order to meet the desires of different stakeholders in detail and to ensure and enhance system operation, each system designer has a range of support components from the MSSS that are available for incorporation into the basic WDSS available to make the whole system work. There are also choices in the WDSS, where technology may have certain minimum management requirements that must also be available, and both the elements of the WDSS and chosen support components must be relevant to each other and the local community. The relationship between the WDSS and the MSSS is that of leverage. Leverage is a means to deal with any misfits between WDSS and MDSS.

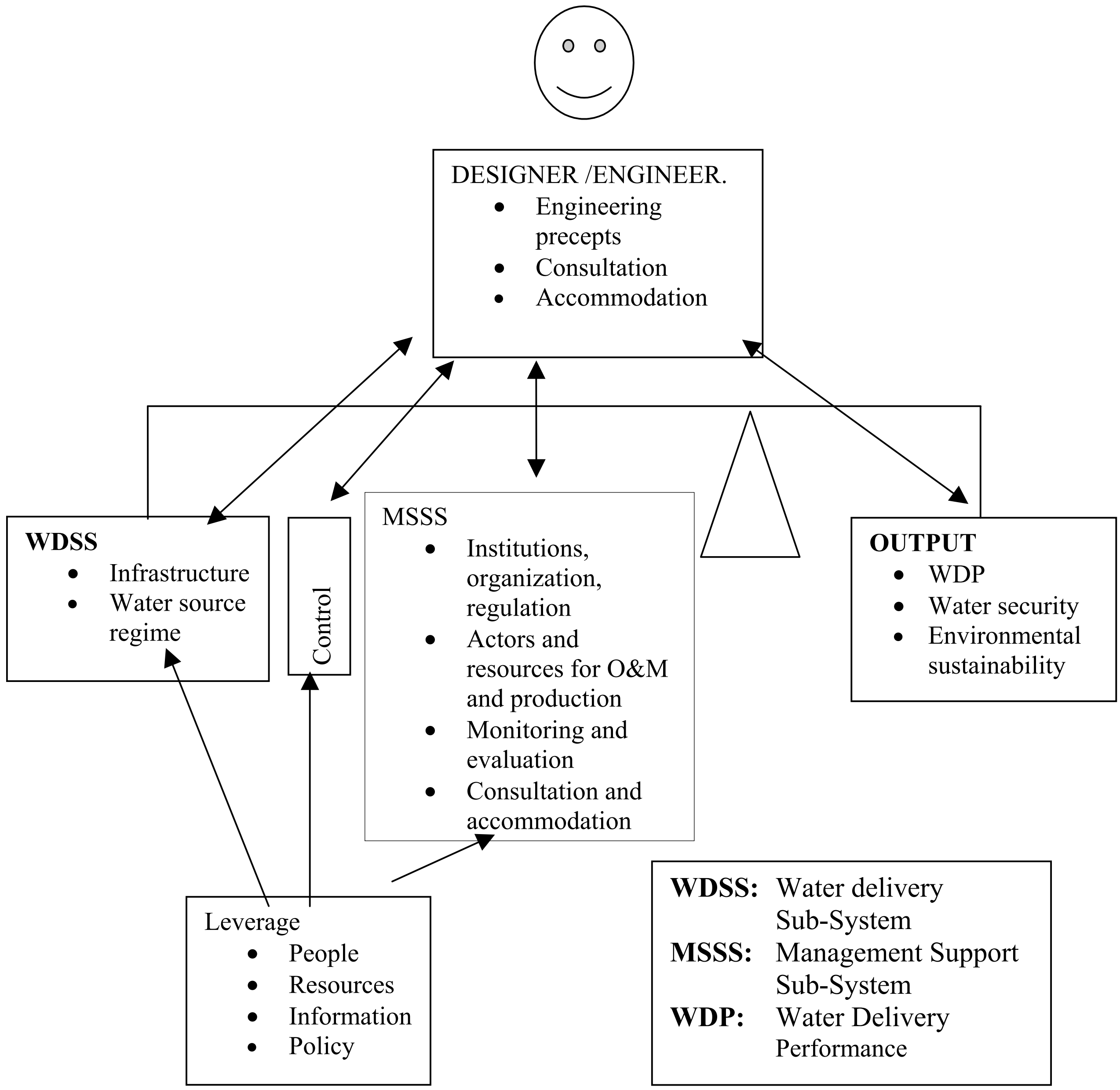
The support components are meant to enhance operability or to support the WDSS in meeting its performance requirements Examples of support components leveraging water delivery are reported in Peru and Mexico. Here operators and the community have made

[19] The rules and roles that Hunt and Kelly refer to are captured through the functioning of the different structures or its service delivery as support for the WDSS. All groupings, both in WDSS and MSSS, have rules and roles appropriate for the direct WDSS or support in MSSS.

[20] Also in keeping with the 'clumsy institution' concept of Thompson (1995) (cited by Vincent in Shivakoti 1997).

arranged allocation schedules perform satisfactorily without major changes in physical artefacts of the WDSS as explained in section 1.5 (Zaag, van der 1992; Vos 2002)[21]. Another simple example is that a road along a conveyance canal is only put in to enhance maintenance of the canal. It does not directly deliver water but it has to be maintained in order to be of use to maintenance program.

Fig 1.4.1 Leverage in Irrigation Water delivery



[21] Zaag (1992) and Vos (2002) found the systems they studied in Mexico and Peru respectively to be performing well and satisfying farmers' needs due to the skills of the operators. These gated systems with low cross regulation would have been expected to be unmanageable when water is relatively scarce (Horst 1990,1998. Plusquellec et al 1994).

1.5 RESEARCHING DESIGN AND MANAGEMENT: ON OPERATIONS, MAINTENANCE AND PERFORMANCE

The key relationships of infrastructure with water delivery and management, with operation and maintenance as critical concerns, are structure control and allocation control. The debates and choices in these controls are reviewed first, before outlining operation and maintenance in depth.

Horst (1998) proposes to simplify the control structures in schemes to match with the current low level of irrigation management support in many countries. He argues that fixed, non-adjusted structures as observed in Indonesia are easy to handle, require no water level measurements, cannot be mismanaged, require few management staff but have low operational flexibility. Horst does not agree with the notion that they lead to low efficiencies by not following crop water requirements. Additional benefits from simplification would be a reduction in the operational and maintenance requirements. This seems a perfect approach for smallholder schemes in gravity surface systems with good drainage, and where equity in the village and neighbourhood are of prime concern.

Lankford and Gowing (1996, pp187-189) also categorised the rigid versus active nature of system design components and configurations, and importantly combined these with the management capacity for determining the potential of a system to meet its ideal performance objectives . The management capacity and level of performance is viewed as an important contributor to the final quality of the delivery schedule. This ability to actualise gated control systems is what Horst and others contest. In Campo de Cartagena area in Spain farmers observed that labour to manage systems is very crucial. The water users association and the water guards decided to invest in water counters to actualise their system after the irrigation agency had withdrawn (van Bentum 1992, pp70).

A number of other system characterisations and classifications based on the infrastructure configuration and in the projected water delivery schedules have been made by Ankum (1992), Renault (1999) and Malaterre (1995)[22]. Albinson analysed canal systems through the concept of 'structuring' and service area or spatial resolution combined with management and hydraulics to describe system behaviour (Albinson 1996)[23].

Clemmens and Replogle made a comprehensive classification of water delivery schedules that did not include the hardware configuration (in Zimbelman 1987). These schedules or water allocation principles are determined by the ability of the system to respond to supply and demand as dictated by the institutions and user arrangements.

Operation and maintenance: critical elements of technology-management relationship

There are lots of studies that have examined parts of the operation continuum and considered or referred to this as irrigation management. Operation is defined by Uphoff (1986) as 'all activities that result in a water delivery being acquired, mobilised, conveyed, divided and supplied or actuated at the desired point which could be the field, farm or plot or the crop as appropriate' (see also Murray-Rust and Snellen, 1993). As highlighted in section 1.2, a key

[22] Renault used four operational levels that is technology (system, and control structures), hydraulics (networks), hydrology (water supply) and policy and agricultural context (consumer, sociology, management and performance). Ankum's classification centred on control makes distinctions between upstream and downstream control and levels and type of automation. Malaterre's classification is based on control engineering and focuses on control logic and control system configurations.

[23] The structuring of a system relates to the levels at which technology requires operation. The service area is the smallest that can be individually served, and the temporal resolution is the smallest time for an irrigation delivery. The smallest manageable irrigation flow for surface irrigation is defined as the lead stream (Albinson 1996).

problem with African irrigation is related to planning, design, implementation and sustained management of non-indigenous technology. This technology in the formal irrigation schemes has a high requirement for scientific, engineering and organisational inputs for its operation. Van der Zaag found that the high operational requirements of gated systems are internalised and used to produce an acceptable water delivery by the action of dedicated canaleros in Mexico (van der Zaag 1992). Manzungu (1999) however found that the operators in Zimbabwe practice contingency management. Some are dedicated and others are more interested in personnel activities outside the water allocation. In either case however there is very little scientific determination of water allocation. Practice is dominated by use of personal experience and judgement.

Maintenance is defined in this study as ‘all the activities that are carried out to ensure that the system is keep in good repair and working order’, that is it retains its capacity to operate as and when required. The UK government accepted the concept of maintenance as both a measure of **cost minimisation** and as terotechnology from the Greek word *terein,* “to care for” (Checkland 1981). Its concern is with the selection, acquisition, care for, and replacement of physical assets. It can be measured by determining all relative costs involved in feasibility studies, research, development, design and production and all support, training and operating costs arising from the ownership and use of physical assets. It entails more sensitive analysis in feasibility studies focusing on options of operation and maintenance and not just overall cost minimisation. The concept of terotechnology is the concern of: managers, designers, engineers, accountants, purchasing managers, information system designers, and users (Checkland 1981, pp 205). Skutsch and Evans have used this relative approach to compare maintenance benefits on two large schemes in South Asia (Skutsch and Evans 1999, pp9-12).

Maintenance as described above entails caring for a given set of artefacts, with the objective of maximising their useful life and thereby maximising total benefits. Maintenance becomes renovation or rehabilitation when the artefacts require a substantial degree of replacement of components of the same type and output capacity, such that the design criteria is retained. This basically implies that the constraints related to non-physical aspects built into the system are not addressed. To address such issues, one has to revisit the design criteria and reconsider the structural and infrastructure needs required by management to support the water delivery subsystem. Such a process is termed ‘modernisation’ of schemes if it seeks to address the current problem situation through re-dimensioning the capacity, use and output potential of the system (Weare 1989, pp15-20). Both rehabilitation and modernisation may involve replacement of parts or all system components. The decision processes for this are related the maintenance policies of agencies, service providers, and farmers, maintenance and financial resource mobilisation strategies. The robustness and resilience of systems, which are important design concerns, also affect the replacement strategy of individual or sets of components. The skills available for diagnosis, as well as execution of tasks and spares availability, are particularly significant for ‘sophisticated’ technology.

Van der Zaag opens up the important debate on actors in scheme operation and maintenance as components as:

> “ *Farmers participate little in water distribution; they do not even feel the need to do so…..Farmers “participate” in cleaning the canals because they have no other option, thereby mobilising social networks at canal level. Gradually groups of co-operating farmers appropriate the canal infrastructure, thereby changing the relationship they maintain with the fellow farmers, with the District officials and the canals*” (Zaag, van der 1992, 203).

The major aspect that inhibits good maintenance seems to be the attitude to terotechnology, and the ability to mobilise the required resources, from irrigation incomes or public finance. This attitude issue requires a great deal of attention, and has complex ties to scheme ownership, empowerment, business acumen, or just passing on own costs to others (like the state) (Savva 2001, Turrall 1995). Tiffen (1987) challenged designers to consider O&M better, and raised concern about poor understanding of the local economy and institutions in design guidelines given by the World Bank[24]. Skutsh and Evans (1999) add to this by highlighting the failure of conventional economists to consider methodologies that support sustainable development "… *the idea of sustainability, by giving absolute importance to future generations, is the ideological opposite of discounting…"*

These findings support the approach adopted in this study that operation and maintenance requirements be considered separately, although they have influence on each other. This separation has also been adopted in recent studies and training in irrigation management by Skogerboe and Merkley (1996), Verdier and Millo (1994) and Snellen (1997). For example Verdier and Millo make it very clear that

> "*Maintenance is necessarily subordinated to operation, much as service providers are subordinated to the clients. This is another way of saying that an irrigation system is at the service of the farmer, not the farmer at the service of the system*" (Verdier and Millo 1994, pp 49).

Carruthers and Morrison (1994) made an extensive review of the literature on maintenance of irrigation and produced a review of the maintenance strategies for irrigation in developing countries. They generally found that there was inadequate financial resources and poor management and recommended that institutions be reformed as an ongoing process to allow farmer participation in maintenance.

Moore (1988) relates the introduction of the water management program that was designed to carry out physical rehabilitation, water management planning and create new institutional capacity as a model. The model failed mainly due to its ambitious endeavour to change farmers' practices with inadequate understanding of what, how and why they do certain things. The model he calls *"simply inappropriate… dangerously irrational strategy"* had been vigorously promoted and turned out in his view to be a *"substantial set-back"*. The way forward he suggested would have been to start by facilitating and encouraging the farmers in maintaining the infrastructure. The government would perform tasks that it can do best like technical repairs to sluice gates, facilitating system maintenance and assisting in mobilising financial resources. The commitment of government could have been provided together with increasing farmer participation by involving farmers and or farmers' leaders and government officials in on-the-spot maintenance inspections. This could then become the basis of maintenance plans that could then be costed and executed jointly. This would leave farmers to carry out all the other operation and maintenance activities at local level using their "complex" but well founded practices. Authorities could also make good and or satisfactory maintenance a prerequisite for access to government or donor support in maintenance or rehabilitation.

[24] "The challenge, therefore, is to design appropriate structures for an area that will yield adequate incomes to farmers, including the payments they make for running costs. Whether they should also pay a proportion of the capital cost is an issue the government should decide in advance of the feasibility study, as this will affect design…. However it is not shown how consideration of the local economy and institutions should influence design, and no mention is made of O&M costs as a design factor, although they are required to be estimated…. The design consideration amplified in the guidelines is concerned with the water supply and technical factors"(Tiffen 1987, pp13-14)

Farmers do not normally consider maintenance for two basic reasons. Firstly poor maintenance might mean they are required to finance repairs and replacement. Secondly they may simply not understand the simple or intricate cause and effect relationship between the functioning of technological components and the inability to deliver the specified irrigation service. Three policy options for planning maintenance have been suggested:

(1) An effective monitoring system is installed to identify when and how the actual situation deviates too much from the desired one, on the basis which the required maintenance is determined and executed.;

(2) On the basis of experiments or knowledge of the system a fixed plan of regular routine maintenance is developed and implemented;

(3) A kind of mixture of the above options: a fixed maintenance plan and schedule together with effective monitoring, that enables flexibility and prioritisation as per available funds (Jurriens *et al* 1993:13, Moore ODI/IIMI 88/24).

Murray-Rust and Snellen (1993) tabled some technical configurations in gravity canal systems that facilitate certain levels of system performance and also are significant for maintenance requirements, as given in table 1.2.

Table 1.2.1 O&M inputs required for different gravity canal system configurations

Component configuration	Operations			Maintenance	
	Discharge at head of canal	Offtake gates	Regulator gates	Canal cross section	Control gates
Ungated overflow	*	-	-	(*)	-
Submerged orifice	*	-	-	**	-
Gates, little cross regulation	*	*	-	*	*
Gates, fixed weir cross-regulation	*	*	-	(*)	*
Gates, adjustable cross regulation	*	*	*	(*)	*
Downstream control	-	-	-	(*)	**
Key to symbols: ** critical, * important, (*) to avoid losses, - no input.					

Source: Murray-Rust and Snellen 1993, pp 34.

Pressurised systems involve moderate to high levels of sophistication of hardware and software, making the availability of parts and technical support important. It is necessary to consider and understand the farmers' capability to repair as well as other replacement and maintenance services (Keller and Bleisner 1990, pp608). Keller and Bleisner made a similar analysis of operation and maintenance requirements for a variety of systems from canal surface, pumped/piped surface, sprinkler to trickle irrigation systems. The analysis was based at system level and therefore failed to capture and differentiate the specific component contributions from a functional and material viewpoint. However they did bring out the impact of pumping on the need for collective action, which is marked by reduced "divisibility" or ability to deliver or utilise service at individual plot level. Pumps are also associated with higher "risk" and "low ruggedness" for breakdowns compared to gravity systems referred to as "canal systems".

Utility Models- Asset Management

The utility model being championed by hydraulic engineers (Hofwegen 1999, pp131-143; Malano et al 1999, pp100-127; Burton and Hall 1999, pp145-163) is based on the need to ensure infrastructure sustainability. This is done through a process of monitoring the performance and value of each system component. Periodic audits on infrastructure are carried out that form the basis of taking appropriate action lead to the release of financial resources to ensure that the service level is maintained at a desired level.

It has been realised that most major hydraulic infrastructure lack care due to the lack of resources when required. This is mainly due to the poor planning and accumulation of funds for the necessary works. In order to address this issue it has been proposed that management of the infrastructure be liberalised to include work by professional companies. Governments and the appropriate authorities would then only be charged with regulation and control. However, the issue of common heritage requiring care, but no private ownership, is elaborated as the reason for government or other public or private institutions to effect sustained O&M (Plantey, 1999; Burton and Hall, 1999; Brewer and Sakthivadivel 1999).

This approach can be tried for schemes where the ownership of most hydraulic infrastructure rests with governments, but the government is also eager to get private sector participation. This case obtains in countries like Zimbabwe. However the fundamental assumption for success and implementation of this approach is that the service provider should be able to charge directly for the water delivery service. This condition has to be considered by authorities in the prospective countries.

Studying the outcomes of management of technology

In order to guide designers, managers, farmers and financiers there is need to provide some guiding criteria of the performance of "artefacts" under specific conditions. There are many performance indicators that have been defined by different disciplines for irrigation assessment (Manor *et al* 1993, Bird 1992, Makadho 1994, Murray-Rust and Snellen 1993, Wahaj 2001, pp12-13, Rao 1993, Vos 2002). Among the more direct indicators that can de studied is the water delivery performance (Makadho 1994 and Nijman 1993).

The water delivery performance is the ability of the system to supply targeted water supplies to a specified part of the irrigation system as measured by selected quantitative measures. For an individual farmer, under conditions of adequate water supply, the most important delivery performance issues relate to the reliability and adequacy of supply. The farmers normally attribute failure to satisfy their perceived needs to improper operation of the system by the responsible individuals or authority. Normally they express their dissatisfaction by launching complaints directly or through a specified channel, but may also tamper with the technological components (Wahaj 2001, Horst 1998, Mollinga 1998). However in many situations the real cause of poor operation may be faulty design, lack of maintenance, simple lack of transparency on the system capability and poor communication between engineers and designers (Horst 1998 pp74-82, Scheer 1996).

Simple indicators of water delivery performance that have a direct relationship to operation and maintenance need to be identified. Different countries have different criteria for a satisfactory delivery service. In cultures where sharing is predominant, equity is more important. In countries like Zimbabwe, where the culture of irrigation is fairly new, individual satisfaction has tended to important. This is supported by the predominance of gated systems with little cross-regulation or fixed cross regulators that offer flexibility. Off-takes without cross-regulators are very few, and mainly found in small off-takes from main canals. Most off-takes have fixed long weirs, and in a few cases duck bill weirs. These structures have high operational requirements, as the reliability of the deliveries depends on the proper setting of each gate. Discharge fluctuations are passed down to downstream gates. Maintenance requirements are fairly low for off-takes with fixed cross-regulators. Head discharge relationships require that sediment be frequently removed from the weir for proper operation (Murray-Rust et al 1993, pp55-61). The biggest weakness of these gated canal systems with fixed regulators is their poor response to water scarcity.

There is a need for a clear response procedure for water scarcity, as failure results in scarcity being sent down to the tail end (Murray-Rust 1993, pp61 and Tiffen 1990, pp15-20). Gated systems that are well-designed and managed can deliver water accurately with rotational delivery schedules (Lankford and Gowing 1996, Albinson 1996, Murray-Rust and Snellen 1993). To measure the water delivery performance of these schemes one needs to measure both the discharge at different outlets and monitor the duration and frequency of deliveries preferably under conditions of adequate water supplies. This provides the parameters to quantify the adequacy and reliability of the system. If conditions of water scarcity exist, the response strategy needs to be identified first so that the target delivery schedules are defined before evaluation of the system performance parameters. Failure to follow this procedure can lead to false evaluation of system performance.

The same measurements can be taken for sprinkler systems with either continuous or rotational delivery schedules. The major variation is that the lateral discharges are measured instead of the canal flows. The indices of relative water supply and timeliness indices can be used to compare performance across schemes (Makadho 1994). However for operation and maintenance purposes, it is more important to monitor the performance of the same scheme before and after an operation and maintenance intervention against the design specifications. This is crucial to achieve real improvement in irrigation management with farmers appreciating and taking ownership of the changed system (Moore 1988; pp5, 9).

The interpretation of the indicators needs to consider the farmers' actions. Levine (1980) found that in some canal systems "*water was used as substitute for labour and water allocation as an equity concern to lessen conflict*". Some farmers in the Jordan valley were found to apply more water using drip systems than traditional surface systems. The drip system was installed to save labour (Vos 2002 citing Wolf et al 1996).

Measurement programs to evaluate water delivery performance and role of operation and maintenance

The SSM approach recognises the need to define both qualitative and quantitative performance parameters, which can be used to validate the success of approaches to change the problem situation (Checkland 1981, 147p). Murray-Rust and Snellen also justify irrigation performance measurement programs from a business viewpoint (Murray-Rust and Snellen 1993).

Quantitative parameters are necessary as they provide a standard to set the monitoring of structural and procedural changes, and also enrich the debate on the management of the sector[25]. Performance measurement of irrigation schemes has been the subject of research and debate for a long time. The selection of performance measurements for the study considered indicators that are:

⇒ simple to monitor at farm level.
⇒ reflect the scarcity of the water resources in semi-arid areas,
⇒ allow the farmer to use them as measures of performance,
⇒ transparent to both government workers and farmers.

The performance indicators that can satisfy these criteria for the water delivery performance should focus on the three fundamental dimensions for which a water service can easily be observed, measured and monitored that is time, flow rate and frequency of delivery. Makadho considered the time aspect of reliability using timeliness indices and used the Relative Water Supply (RWS) to measure adequacy (Makadho 1994, 1996). Murray-Rust and Snellen (1993) used the delivery performance ratio. Other measures of adequacy that are

[25] "In management they say if you cannot measure it then you cannot manage it" (The financial gazette June 21, 2001;Moorhouse 1999, pp176)

appropriate for the measurement of adequacy are given by Molden-Gates and Oad (Bird *et al* 1992, Oad *et al* 1990). Gini and Christiansen defined equity indicators. Abernethy developed interquartile ratios. Rao summarised this generation of irrigation performance indicators (Rao 1993). Wahaj also summarised some commonly used water delivery performance parameters; adequacy, equity, reliability, efficiency and productivity their definitions and indicators (Wahaj 2001, pp12-13). Another generation of indicators for comparison between systems has a set of nine indicators as compiled by IWMI and summarised in appendix 1.2 (Molden et al 1998, Kloezen 2002).

Malano and Burton (2001) have proposed a benchmarking approach to performance. They have incorporated a wide range of indicators, and clearly separated service delivery performance from financial, productive and environmental performance. This study agrees with this separation but classifies all the other performance indicators as secondary and related to the management support subsystem. This approach allows a clear focus on the water delivery service in its operational environment. To treat these performances as equally important in all analytical platforms would be letting down the farmer who is supposed to make final decisions as to importance of each service in a particular instance.

In summary, for each scheme there is need to determine the most appropriate performance indicators considering the practical limitations and usefulness of each indicator. For the comparative purposes of this study, Relative Irrigation Supply will be computed for each system at levels dictated by the technology of the system. Farmer-based or internal process indicators like stream size and timing will be qualitatively reported for each scheme as they relate to the fine tuning of the delivery service. Christensen uniformity indicators are computed for sprinkler schemes where possible.

Maintenance performance measurement

The maintenance performance can be measured through the number of scheme items, in terms of the **relative** contribution towards the minimisation of ownership costs - which is given by the ownership cost divided by the life time of the artefact (Checkland 1981; Skutsch and Evans 1999). This implies that for smallholder schemes the designers, the farmers, the management committees, and other related government and non-government organisations are all involved in the process of cost minimisation. By determining the actual costs and discounting them for time and inflation, it is possible to quantify the level of cost minimisation for selected items under different conditions and schemes (Skutsch and Evans 1999). It may also be possible to use the different operational conditions to carry out a sensitivity analysis of the different design options. This approach was used to re-evaluate the choice of system components design at Mpudzi and Bonde, as is discussed in the respective case studies. The findings on the operation and maintenance requirements for Musikavanhu were also re-evaluated by a consultancy during the study period using the same approach as discussed in the case study.

From these studies it may be possible to re-examine the designs of systems, and their operation and maintenance, and using some common indicators, to determine whether they are the right designs, and capable of being operated or maintained in the right way to produce their intended outputs. In order to determine whether the designs are 'right', one needs to understand the perceived need of the irrigating community.

The main research question was thus formulated as:

What range of irrigation system technologies are found in smallholder irrigation in Zimbabwe; how and why do they differ in technology and management arrangements; and how well, and why, can current management systems undertake operations and maintenance and leverage effective water distribution in different irrigation systems?

Sub questions

What are the key changes in irrigation concepts in smallholder irrigation in Zimbabwe? What water delivery and management support systems are associated with them? Why are these changes occurring?

What elements make up the management support subsystem, and how does it interact with the technology of the water delivery system to shape water control?

What are the everyday practices of O&M in schemes designed with different irrigation concepts? How do these relate with original design proposals?

What patterns of water delivery performance are found in these different systems? How do operation and maintenance realities shape these performance outcomes?

1.6 METHODOLOGICAL DESIGN

A case study approach was selected for the study, with a study of six systems that represented core examples of the changing technology trajectory of smallholder irrigation in Zimbabwe. Case studies were selected as a methodology because of the powerful effect in bringing out the realities of everyday activities at each irrigation scheme. Due to the strong influence of the human element in smallholder irrigation, it is not possible to accurately control or have similarities of schemes that warrant the use of standard comparative logic as applied in hard scientific research. Therefore in order to learn the realities of design, operation and maintenance it is necessary to understand the reality on selected schemes that offer a diversity of technological and social settings. By studying these live forms one can reasonably anticipate the creative output of future designs with respect to O&M.

Schemes for detailed study were selected based on the following stratification criteria:

1. The schemes had different water supply sources, from among the main sources in use: these were the run-of-the-river, small to medium dams and large dam supply. Borehole sources were also considered.
2. They had the major technological artefacts for water delivery found in Zimbabwe had gravity conveyance and distribution by pipe or canal, and surface of overhead water application.
3. The schemes were either in need of maintenance or sound operation or redesign with a strong probability of the physical process starting during the two years of the study or the schemes were actually in the process of being maintained, upgraded or rehabilitated.
4. Plot holdings were close as possible to the average of 0.8 ha per household.
5. Scheme sizes should be greater than 10 ha and comprise a minimum of 10 farmers for meaningful statistical inferences to be made.
6. Schemes with some comparable features were preferred as this helped to get more insight into the difference attributable to the major stratification criteria that is 1 to 3.
7. Schemes included both agency and farmer managed schemes.
8. Schemes had not been subjected to many studies before especially in the last twenty years. For this reason the following schemes had not be considered in this study: Nyanyadzi, Mutambara, Chibuwe, Tawona and Nyamaropa: These schemes have been studied by Makadho (1994), Bolding (1996), Manzungu (1996, 1999), Vijfhuizen (1998), Magadlela (2000) and Pearce and Armstrong (1990).

In order to provide continuity to the first phase of ZIMWESI and for logistic reasons, the selection of schemes prioritised first those in the Chimanimani district, followed by the schemes in Manicaland province close to it.

The choice of schemes represents the different technological combinations of lift against gravity, surface against overhead, conventional against draghose and proportional against gated which gives at total of eight scheme combinations. For detailed study four schemes were initially chosen. Two schemes were later added in order to help to amplify the basic technological attributes "perceived by Agritex as the future"[26]. These were the lift with overhead and draghose distribution systems, against the surface with gravity and fixed regulators before gated outlets for control and regulation that formed the "old colonial baseline design". The six were also representative of the mixture of agency or joint-operated and maintained schemes that are today's norm and baseline, against the purely farmer-operated and maintained system, which is " government's future wish". The detailed studies were also hoped to address the actions and options in market oriented production that is high on the "government's future wish list" against the subsistence or 'livelihood' production which dominated most of the existing older systems.

The schemes finally selected were Mutema, Bonde, Mpudzi, Deure, Chakowa and Musikavanhu as shown in table 1.6.

Table 1.6 Summary of study schemes

Scheme name	Block	Area (ha)	Number of Farmers	Management Agency
Chakowa	A to D	87	115	JMIS
Deure	A to D11	87	115	
Mutema-sprinkler	B1 B11	90 90(damaged mid-way)	96 98	JMIS
Bonde-	A C1	160 100	260	FMIS
Musikavanhu	A1	72	60	FMIS
Mpudzi	Upper block	25	25	FMIS
	Lower block	25	25	

Data Collection

Fieldwork took place in the period June 1998 to August 2000 with data collected as shown in Appendix 1.6.1. The first summer season starting September 1998 was a preparatory period for: reviewing reports, appraising sites, preparation and testing of questionnaires, installation of equipment, testing and initiation of field data recording. Most intensive data collection on field practices and flow measurements on all schemes took place during the period March 1999 to February 2000 that covered a winter and summer cropping season. Some schemes were only temporarily disrupted by Cyclone Eline of 23-24 February, 2000: however Chakowa, Mutema and Mpudzi were severely affected and no meaningful measurements were resumed.

Local Agritex staff, farmers and farmer representatives did most of the observations on all six schemes. This was done by means of field record books given to the different

[26] The six schemes represented all the eight technological combinations because two schemes i.e. Mpudzi and Musikavanhu had system components which cut across the normal system configurations. The Mpudzi had gravity supply into piped draghose application and Musikavanhu had pumped supply into canal surface application.

individuals involved. To build links with field staff the field record books were in all cases handed out through the local extension staff by the researcher. A discussion session was held in each scheme to explain the objectives of the study and how it was likely to influence or benefit the farmers. The extension workers (EW) and farmer representatives or local staff then discussed procedures again with the researcher and an exercise to design the appropriate data entry table was undertaken. Farmers' specific requirements or understanding were used to determine the data entry at each scheme. Some basic parameters recorded were plot registration or identity, irrigated crop, date of start and finish of irrigation event, crop planting date, area irrigated in appropriate measurable units, number of discharge units (siphons or sprinklers). The farmers who carried out some of the measurements provided a useful source of farmers' views on technologies and their requirements. The continued interactions with them provided insights into local perception not found in schemes that were monitored by students and research assistants.

Data on maintenance was collected on schemes by engaging farmers and local staff in recording of their daily activities. In government-managed schemes with specific maintenance staff in post, that staff was interviewed and their activities monitored (Deure, Chakowa and Mutema). On farmer-managed schemes there is no clear allocation of responsibility. Therefore most information obtained was through observation and discussion with the help of research assistants at Mpudzi, Bonde and Musikavanhu.

Evaporation pans and rain gauges had to be installed on all the six schemes[27]. There were considerable differences in the way the exercise was undertaken by the government managed and farmer managed schemes. At government managed schemes the recording exercise was generally taken up well. Office orderlies were trained by the EW to undertake the task. The recording at farmer-managed schemes was generally problematic

Flow measurements were developed around existing practices on the different schemes. The government schemes already had procedures for recording inflow into the scheme, and these were used to study hydraulic performance at system level. Where relevant, flows were also measure at the intakes of the study blocks. For pumped systems, delivery was calculated from operating pressure and pumping time records. These measurements were used to assess hydraulic performance at system level. Flow measurements were also taken in blocks under intensive study in Chakowa, Deure and Mpudzi.

Informal interviews and crop surveys were made during the whole study period by the research team. This was mainly based on informal discussions and observations. Calculations of crop water requirements were done using the FAO Crop Water Requirements (Penman Monteith method). The Relative Irrigation Supply (RIS) was computed for all schemes using the actual water delivery (AWD) data and crop water requirements (CWR) of the actual cropping patterns averaged over schemes or scheme blocks as given below in equation 1. It was also possible in some schemes to determine some basic parameters for the water delivery schedules.

$$RIS = AWD/IWR \qquad (1)$$

where RIS is the relative irrigation supply
AWD is the actual water delivered and
IWR is the crop water requirement of that particular crop pattern excluding rainfall.

[27] Only Deure and Mutema schemes had class A evaporation pans but they were leaking and beyond repair due to rust at the base. There were no rain gauges. Deure also had a fibreglass Dore and Pitt pan but it had not been calibrated against the standard pan. New pans were bought half as stock items and the other half on order from a Harare company.

Some constraints related to studying-own-working-situation

The study program presented some practical difficulties in its implementation. In the systems of Deure where the researcher was personally involved in past implementation, the requirement to be impartial in judging one's own work was not always easy[28].

The farmers' actions towards me as an Agritex official and the desire for independent study of processes were sometimes in conflict. In Mutema, farmers indicated to me that they expected an improved delivery system first before they could engage in further debates on production and water management issues. Some farmers viewed the exercise as a window of opportunity to air their views. In Mpudzi, I discovered how someone used my name to gain access to a plot only to dispose of it soon after as outlined in the Mpudzi case chapter 8. These experiences are outlined further in each case study.

An even more difficult issue was the process of having to question colleagues both above and below oneself in the official hierarchy. Using the information so obtained to reconstruct and trying to redefine future options proved a painful experience. I tried to emphasise the importance of learning as the guiding principle in the research effort, but it is feared that a number of individuals perceived the study as an act of recrimination. The reconstruction of the Bonde planning and design was particularly difficult.

1.7 OUTLINE OF CHAPTERS

This document is presented in four sections.

Section A gives an overview of the problems affecting smallholder irrigation schemes. It looks at the problematic of smallholder irrigation in relation to the design – management relations in Zimbabwe. It puts the smallholder irrigation development situation in Zimbabwe alongside the global debate and then reviews specific technical and institutional issues for Zimbabwe. Chapter 1 has reviewed relevant debates with respects to operation and maintenance of smallholder schemes. Performance measures have been discussed as a way of providing proxies for use in assessing the adequacy of designs, operation and maintenance. It has outlined a theoretical approach, combining a sociotechnical analysis with soft systems methodology, to focus on the concept of leverage. The criteria for selection of the six case studies have been explained. In Chapter 2 the Zimbabwean smallholder subsector is reviewed with particular emphasis on the policies and realities shaping development and management of the schemes, and the "engineering precepts" that shape the current impasse in action to promote locally sustainable systems. The technological debates and the thinking processes governing choice of irrigation systems in reviewed. The institutional issues examined give particular attention to the roles played by Agritex and DWD/ZINWA. These help to show the infrastructure configurations that provide different opportunities and challenges to individual use and local management.

Section B and C explores through six case studies the technology-management interactions in smallholder irrigation in Zimbabwe, particularly the realities and stresses of water delivery experienced by farmers. Irrigation operations and their relations with the maintenance in different water mobilisation, delivery and application systems are examined at each of the six schemes selected. It deals with the Water Delivery Subsystems (WDSS) found in Zimbabwe. Section B examines the situation on three old schemes, by Zimbabwean standards, that is Chakowa, Deure and Mutema. Chapter 3 and 4 examines examine in turn

[28] At the start of the study the researcher was Chief Irrigation Specialist. In March 2001 he was transferred to the post of Chief Soil and Water Conservation Specialist. In December the same year the researcher resumed the post of Chief Irrigation Specialist in the Ministry of Rural resources and Water Development where a Department of Irrigation was later formed.

the gravity intakes, canal conveyance and surface irrigation at Chakowa and Deure. The realities of practice, and contributions of specific design attributes, are examined in relation to the changing or “declining” maintenance situation. Chapter 5 considers the alternative water mobilisation system of lift irrigation at Mutema. The practices in pumping and water control are examined with the aim of drawing lessons for the new Bonde and Musikavanhu schemes discussed later.

In Section C the new schemes Musikavanhu, Bonde and Mpudzi are examined in turn, in chapter 6,7 and 8, to get an insight of the benefits of the different “technological repertoires” and management interventions. Overhead irrigation from river and borehole sources is examined, and its requirements for operation and maintenance. The contributions of the design, technology, organisations are considered. These new schemes were developed with the policy of irrigation management transfer (IMT). The farmers' responses to the challenges of taking care of operation and maintenance and some of their coping strategies are examined. In Chapter 6 proportional division structures at Musikavanhu are examined, and the effect of the pumped water supply is considered. In Chapter 7 practices at the Bonde pumped draghose sprinkler system are examined. The Mpudzi case, in Chapter 8, is of a gravity overhead draghose application system. This helps to put the technological debate on the relative contribution of pump and piped overhead application into perspective. In all the case studies performance measures are reviewed in terms of crop based scheduling and opportunities for flexible water delivery.

Section D provides the reviews for this thesis. Chapter 9 compares and reviews the Management Support Subsystems (MSSS) found on all the schemes. The management issues relation to the old systems of Mutema, Deure and Chakowa are reviewed in relation to operation and maintenance. The effect of the shift in support services policies and its effects on the schemes are considered, and the response of farmers and local institutions to this shift. Chapter 10 gives the conclusions of this research, there is a review of the findings, key themes, and experiences in smallholder irrigation policy. It also reviews the adequacy of the theoretical framework and the methodology. Some recommendations for future work are suggested.

2 TECHNOLOGY CHOICES, INSTITUTIONAL CHANGE AND TECHNOLOGY CARE IN IRRIGATION MANAGEMENT IN ZIMBABWE[1]

2.1 INTRODUCTION

This chapter investigates how smallholder irrigation in Zimbabwe has seen a trajectory of technology from simply gravity distribution to pump and pressurised overhead sprinkler systems in a paradigm linked particularly to control and efficiency in both technical and institutional terms. What has not been thought about enough is how to design technology and management together, so both are viable in given local contexts, and how they work together to provide the water supply and technological care necessary to keep an irrigation system working. These problems stem from the policies and politics of the different public institutions that interlock for the construction and operation of irrigation systems.

Zimbabwe's history as both a colonial state and a transforming rural society has made state bureaucracy a critical actor in its land, water and production management. It has also been influenced heavily by external development assistance and international finance that has led to the transformation of the science and administration underpinning economic transformation. This section examines the changing institutional structures directing agricultural and water management with technical experimentation in irrigation supply to show the emerging management dilemmas for local operational management of irrigation systems.

The history of smallholder irrigation development and government programmes has been well documented elsewhere. Zawe (2000) made a historical review and linked the evolution of smallholder irrigation with the land settlement and development policies of the government. This chapter presents an overview of changes in irrigation design. This sets the scene for the slow separation and decline of arrangements for operations and maintenance (O&M) in favour of a growing emphasis on technical design and implementation that delegated or almost completely transferred operational management to local extension staff and farmer committees. By the year 2000, the changes also left a growing confusion between the work of the Department of Water Development (DWD) in the Ministry of Water Resources and Agritex especially as Agritex pursued more sophisticated pressurised irrigation systems supplied by pumps. At the time of writing, Agritex itself had been split up - though it still had an irrigation section - the Ministry of Water had become the Ministry of Rural Resources and Water Development, with the DWD being transformed into a Department for Irrigation and Water Development. These were later split into two separate departments of water development and irrigation.

2.2 THE CHANGING TRAJECTORY AND IRRIGATION TECHNOLOGIES IN ZIMBABWE

Smallholder irrigation started with gravity canals and surface irrigation methods, initially through small furrows. Schemes were usually on highly productive alluvial soils, close to rivers. Some authors suggest early small local schemes emulated the technology of first white

1 This chapter was jointly authored and published by Linden Vincent and the researcher, in Moll and Manzungu (eds) 2003. Linden Vincent is Professor of Irrigation and Water Engineering at Wageningen University.

commercial settlers and missionaries in the period 1912 to1927. Initially the Ministry of African Affairs only helped in scheme development. In the period 1927 to 1945 it started taking over management and control under the name of famine relief. It also introduced "compulsory crops" like wheat and beans (Zawe 2000).

Within schemes, the seasonal water supply meant a rotational distribution was put in place in larger systems, rotating available supply across canals supplying sections of the system. A fully fixed rotation had the least capital investment and involved least operational input.

Diesel-powered pumps for lift irrigation first arrived from the 1940's. Lift schemes were adopted in sites where long conveyance canals were unfeasible or insecure (confluence areas prone to inundation), or because they could serve a much larger irrigated area than could be supplied by a gravity canal. Pumps brought new challenges to operation and maintenance.

Possibilities to irrigate larger areas meant that variable soil types were found within schemes. Lighter soils came under irrigation, bringing concern over in-field losses for the first time. Sometimes even naturally saline soils were encountered for the first time.

With the Land Apportionment Act in 1945 to 1956 the Department of Native Agriculture (formed by the merger of Internal Affairs Administration and Ministry of African Affairs) took over development and management of smallholder irrigation. New schemes were set up with the objective of settling blacks displaced by whites. This led to development of expensive and not cost effective schemes with frequent breakdowns and water shortages (Zawe 2000, Magadlela 1999)

Experiments and designs for new settler schemes (white and black) also brought attention to borewell development with groundwater as a water source. Some blocks of smallholder systems with lights soils were switched to borewell and pressurised sprinkler systems, to save losses. These brought new management challenges but they stayed under government control.

Expansion of commercial farming and exchange of experience from American and Australia also brought gated control structures into the country, although these did not appear to be designed into smallholder systems until the 1970's. Their use might follow the interest in better water control to save water to circulate across larger irrigated areas. They also became more technically feasible once canals were lined and economically feasible as regulated rivers and pumps improved duration of supply. They also physically echoed the emphasis on 'control' that government imposed on smallholder irrigation in the 1970's. The Control of Irrigable Areas regulations of 1970 required farmers to sign annual renewable permits for residence, managing stock and cultivation. This allowed eviction of farmers not complying strictly with payment of fees and cultivation practices.

During the 1970's, lining of canals was promoted to reduce losses, especially in pumped schemes. Its is suggested that overall this was preferred as a 'water-saving' approach to use of sprinkler irrigation. Greater river regulation under dams also began at this time (see below), triggering new dependencies on pumps to lift a more reliable water source to supply economically feasible areas. This also allowed increased size of irrigation systems.

With expansion of canal lining, and of smallholder irrigation, came greater use of gated control structures in canals that are now a virtual standard feature of gravity systems in Zimbabwe. Around this time, probably the balance of operation and maintenance shifted and resource needs also grew, as explained later.

From the 1970's, increasing numbers of medium and large storage dams were built. These gave a more stable and more continuous water supply than the older run-of river schemes. Some dams were utilised for gravity systems. However, others regulated major rivers. This brought new developments of pump lift schemes. These bought new requirements of communication between Agritex staff managing in-system, and DWD staff managing the rivers – but also DWD staff manning the pumps and managing the dam releases. Some staff justified canal lining as a means of saving wastage of this more expensive stored water.

Evidence shows considerable interest and heated technical debates between the different groups designing irrigation, especially the pro's and cons of 'overhead' (sprinkler) irrigation. At this time, levels of technical training and certification were high. A conference at Nyanyadzi showed both DWD and Conex holding negative views on overhead irrigation. DWD saw it as increasing running costs and making crop production uneconomic. Conex saw overhead irrigation as doubling costs per unit area, and warned that sprinklers might have a management problem, such that it might be better to have contracted management than farmer management. The DWD also voiced the view for schemes to employ contract managers rather than let/expect plot holders manage the system. Conex also warned that overhead irrigation would require farmers to irrigate in a fixed pattern. Finally they warned it could have lower irrigation efficiency than a well managed flood application method. Nevertheless, whole schemes or blocks of schemes did transfer under sprinklers.

Statements of the time agreed that DWD was responsible for the delivery of bulk water supply, and their responsibilities ended where water became split up.

While interests grew in different methods of irrigation application at field level, there was little debate at national level over best technologies for supply of water, leaving the pump dominant without attention to design of management principles. With the advent of independence in 1980 opportunities were availed for increased foreign influence in the design, implementation and management of smallholder irrigation. The Department of Rural Development Derude retained the development and management of smallholder irrigation and introduced the concept of irrigation management committees to involve farmers. The design and planning function was transferred to the new department of Agritex[2]. The Derude functions of smallholder irrigation were later transferred to this department in 1985 (Zawe 2000).

During the 1980's new contacts with bilateral and multilateral agencies brought in new scientific interests and emphases on crop-based design, and efficient irrigation systems. Design approaches spearheaded by the Food and Agriculture organisation (FAO) had a major influence. In addition to expanding the number of smallholder sprinkler systems, FAO led the development of draghose systems. Both developments changed the ways farmers might act together to share water, and thus irrigation maintenance and recurrent costs.

Pressurised systems bought higher costs, and for the first time, farmers in one scheme suggested individual metering of plots, as they became unwilling to share high costs equally. Farmers showed variable reactions to overhead irrigation methods, with concerns focusing mainly on the labour demands of older lateral systems, and on problems of replacement of parts. The few available performance studies suggest that no farmers yet operate their field systems to save water. However, pumps have had reduced operating times to reduce costs.

The structural adjustment programmes led to a reduction of government subsidies, including recognition that they could not longer pay for electricity for smallholder irrigation schemes. Attempts to turn over all or part of operating costs led to cessation of irrigation in some areas.

Micro-irrigation had pilot testing at the irrigation research centre, as the most recent of the 'high performance' technologies to be promoted by external donors.

Debates about irrigation policy took place, recognising the problems in irrigation management, with new initiatives to promote irrigation management committees and fee payment. However, no new legislation for irrigation took place.

[2] Agritex was formed in 1981, from the merger of the Department of Conservation and Extension (Conex) and the Department of Agricultural Development (Devag).

During the 1990's, a new Water Act replaced water rights with water permits, and introduced Catchment Councils to manage water (Moyo, and Vincent and Manzungu in Moll and Manzungu, 2003). The Zimbabwe National Water Authority (ZINWA) was created as a parastatal for planning and managing water resources, overseeing catchment councils, taking over the technical secretariat of DWD, which was mandated to develop a water resources management strategy. ZINWA reports to a new Ministry for Rural Resources and Water Development, which now has a new Department for Irrigation. Agritex itself disappeared, with the extension division combining with research to form the Department of Agricultural Research and Extension (AREX) and other divisions forming departments of agriculture engineering, livestock development and irrigation, while the land planning section joined the department of lands. Unclear boundaries for irrigation design and management that developed between Agritex and DWD seem to be reappearing again between the Department of Agriculture Engineering and the Department of Irrigation. Land reforms presented irrigation staff with new problems as commercial farms with sophisticated irrigation technology were resettled, with little knowledge on how such equipment (like centre pivot sprinklers) can be adapted.

Many critical issues stem from the Agritex take-over of the main role in irrigation after 1987. These include the problem of local management in an organisation heavily committed to extension work; the increasingly sophisticated technologies that Agritex chose to promote in irrigation; and the lack of clarity between their role and DWD in certain technical matters concerning water delivery. Questions for O&M also materialised from the technical design choices of Agritex as they moved away from simple gravity systems into pump/lift and pressurised overhead (sprinkler) systems. These can irrigate larger areas and may allow better delivery of crop water but are very expensive to operate. Also the development of larger, gated surface delivery systems increased demands for operational personnel.

When representations to transfer the irrigation section from the Derude part of local government were made, the main justification raised was that technically irrigation is a farming enterprise. The transfer was done at divisional level with the unit headed by a deputy director (irrigation). On merging into the Agritex structure, there were two posts of chief irrigation officer, one from Derude and one from Conex. An incumbent from Conex, who mainly provided technical services, filled one post. It was then decided to scrap the other chief post and break it up to create lower posts at provincial level. It is understood that some equally high ranking officials within the organisation warned that cutting this post was likely to impede service delivery. In the earlier period, Conex had responsibility for design and planning whereas Derude took care of construction and management (with DWD also active for dam and borewell works). The balance between technological care and necessary institutional support never recovered, although it could have been predicted that a decline was inevitable.

What emerged in the Agritex irrigation division was a growing emphasis on design, implementation, research and training with little attention to the operation and maintenance (O&M) of systems. Instead, O&M became the task of the extension staff in the field division, which will be explained later sealed the problem. At the local level irrigation schemes were left without administrative, financial and strategic planning capacity once available from the local government framework, where capacity to drive byelaws, procedures and legal guidelines also lay dormant. The draft policy paper sponsored by FAO in 1994 could have remedied this problem. However, the policy discussions neglected important issues involved in ensuring sustainability and improving water delivery particularly those that involved the way infrastructure should be chosen, operated and managed. Instead they concentrated on crop-based design and the economic aspects of irrigation investment and irrigated production. The training programmes supported by FAO also helped to focus attention on pressurised delivery systems. It is, therefore, not surprising that Agritex headquarters eventually had to start calling for subsidies to help those smallholder irrigation schemes that were failing to sustain themselves. In fact, the Irrigation Division never had irrigation staff posts below provincial level (Irrigation Specialists). Zawe (2000) points out that generous funding for the establishment of schemes - often managed at headquarters rather than provincial level - was not matched by good financing of O&M and this meant that extension staff remained under-resourced.

Until 2001, when work on this study came to an end, Agritex was responsible for the O&M of canal schemes. After 1987 - during the consolidation phase - Agritex rationalised irrigation staffing and placed system O&M under extension staff. The extension services could not prioritise O&M. They had no training in operating and caring for water delivery artefacts nor were they given resources. The situation has been compounded by the focus of the Irrigation Branch of Agritex on the development of pumped irrigation schemes. After these had been started up they were left in the hands of extension workers who were already overloaded with work. (Makwarimba and Vincent in Moll and Manzungu, 2003). These individuals also have very little if any administrative and financial training to assist farmers in mobilising financial resources, or in guiding them on how to utilise and account for them. In such situations extension personnel tend to leave things to chance. Not surprisingly, many schemes - gravity, surface, pumped and sprinkler - now need repair or O&M assistance. The extended Small-scale Irrigation Support Programme (SISP) working with Irrigation Management Committees, and the Agriculture Revolving Fund[3] programmes have been strategies developed to address the issue of system operations from a management and financial point of view.

Mergers have also given rise to other tensions in recent years. As the above table showed, DERUDE began to work more seriously with Irrigation Management Committees from 1983 onward. The DWD, however, in earlier statements had voiced the opinion that schemes should employ contract managers and not expect farmers to manage systems (particularly systems with pumps). In recent programmes of Irrigation Management Transfer it has been difficult to get the salaries of pump operators trained by DWD funded by the Irrigation Management Committees (see Section 2.4).

The complex technological trajectory followed by Agritex and the increasing numbers of systems designed and constructed by Agritex also bought their own dilemmas. The government managed schemes that had pumping units had their repairs, maintenance and operational costs met directly by government institutions. These institutions, therefore, became the clients of the power supply authority and were responsible for paying for the electricity used in lift irrigation schemes. The DWD supplied all diesel fuel and carried out repair and maintenance on pumps and motors. It used its workshops in Mutare and other towns or contracted out companies to effect the works. As for gravity open canal and piped systems, Agritex maintenance gangs did the physical works. Some gangs were initially employed by DWD who supervised the construction of some canals such as those in Deure. These were then handed over to DERUDE and eventually to Agritex.

As far as the maintenance of gravity open channel systems were concerned DWD's strategy has been to hand over responsibility to the Ministry of Agriculture - first Devag, later DERUDE and finally Agritex. DERUDE and Agritex in the old schemes had management structures whose specific purpose was to carry out this type of work. The Agritex local establishment at each scheme, therefore, tended towards an organisation that clearly separated individuals responsible for water management and those responsible for extension.

[3] As described later, this fund allows Agritex staff to charge for certain services supplied e.g. consultancies, including to field organisations, but it has its critics - see also footnote 10.

Two examples show the lack of clear boundaries between the staff of DWD and those of Agritex who designed, constructed and operated the systems. The first story comes with Mr Ch. He is a plot holder and a retired former maintenance foreman at Deure having been transferred to Agritex from the Department of Water Development (DWD). He started working for DWD in canal construction and was involved in the development of the Odzani canal. Later he was transferred to the Mutema canal and he and his gang were also involved in the development of the Deure domestic water reticulation system construction. He was then transferred to Agritex to head the Deure canal maintenance section - a post he held until his retirement in 1996. The DWD is understood to have constructed the Mutema canal and was initially responsible for its maintenance. They later handed over the maintenance of the canal to DERUDE, who subsequently handed over the task to Agritex. Agritex was responsible for maintaining all smallholder irrigation canals irrespective of whether they were constructed by DWD or Agritex. The question of maintenance is less clear with pumped schemes, as shown in the case of the boreholes at Mutema and Musikavanhu.

The DWD spearheaded the development of the Mutema boreholes in 1970 and have retained the operation and maintenance of the pumps up until today. They are also responsible for pumps at Chibuwe, Tawona, Nyanyadzi-Nenhowe, Bonde and Nyakomba irrigation systems. However, the situation differs at Musikavanhu irrigation schemes where the DWD were only involved as borehole drilling contractors. Here Agritex worked closely with a technical expert team and spearheaded the development and installation of pumps in the boreholes without input from the DWD. This headwork responsibility is, however, different from the other schemes that were developed at the same time by Agritex - namely Bonde and Nyakomba - where the DWD was the main agent responsible for pumped headworks. In these schemes, while Agritex was the main implementing agent, there was a clear partnership with DWD who were responsible for the pumping plant. Thus the old allocation of jobs was maintained as required - that in Manicaland all pump maintenance and operation staff be DWD employees. This is the case for all schemes except the Musikavanhu scheme. Agritex's only assistance was to pay for maintenance and operation costs through the DWD account. Until 2000, farmers on the Manicaland pumped schemes did not have to pay directly to DWD.

2.3 THE FATE OF OPERATIONAL IRRIGATION MANAGEMENT: OF MANAGERS, MANAGEMENT COMMITTEES AND IRRIGATION FEES

Since the start of smallholder irrigation there have been a number of policy and legislation changes that have influenced both the provision of services by the state and redefined the interface with farmers. These changes have been mainly in the area of management structures and charges levied by Agritex for water, maintenance, and operational services. This section first reviews the institution of the 'irrigation manager' and later the Irrigation Management Committees. It also looks at fee charging and management.

The fate of the 'irrigation manager'

The initial policy towards smallholder irrigation was to consider irrigation as a privilege. Therefore those engaged in irrigation had a duty to optimise resource use. This was formalised by the Control of Irrigable Areas Act (1970). Smallholders were expected to obey instruction and behave almost like contract workers. Some say they were expected to behave "like children" (Reynolds 1969 in Manzungu 1999, p.32). An individual had to pay rates by a prescribed date and follow the manager's prescribed cultivation practices in order to be eligible for a permit. These permits were renewed annually. There was no security of tenure and, at that time, this was not even considered desirable as it could lead to the "privileged" irrigators becoming less diligent. To ensure that the permit system and other controls were strictly adhered to, a white manager was put in charge. This control might be linked to the resettlement of displaced peasants in the irrigation schemes in the period 1946 to 1956 (Manzungu 1999, pp169; Magadlela 1999). This legislation saw the introduction of new crops like cotton and the compulsory rotations of beans and wheat (Manzungu 1999,32). Farmers were expected to use required inputs and strict and "competent" demonstrators ensured compliance (Magadlela 2000). Individuals with agricultural training provided extension services at schemes. Magadlela gives some detailed account of the work of these cadres who were then referred to as agricultural *madumeni* (demonstrators) (Magadlela 2000), and not 'extension workers'[4].

However, there was a clear focus and emphasis on the need to ensure that plotholders received a regular supply of water. Simple, robust technologies with low running costs were therefore chosen to meet this requirement – gravity distribution systems and surface irrigation. The District Commissioner enlisted the services of technical experts from Conex and DWD for this purpose. The plot holders paid one charge that took into account all the scheme requirements.

Thus the first management model for government-funded smallholder schemes had an irrigation manager, who headed a team that carried out operation and maintenance. The managers, who were initially whites of various backgrounds, concentrated on ensuring that the infrastructure was kept in good working order. One of the present authors worked with the late Mr X who used to manage Nyamaropa irrigation scheme. Although his formal training was unknown to the author, he had great practical experience in planning and executing repair works and procurement. He was well connected to civil contracting companies and was also very good at costing jobs and accounting for project works. The operation and maintenance gangs were kept hard at work on a variety of tasks including cleaning canals and repairing structures, but also on fencing and general work relating to the infrastructure of the schemes. All this work was meticulously logged. Technically sound provincial irrigation specialists, also white, supported these managers. These left after the mergers, some emigrated but some remained to work in private companies or as consultants. This emphasis on maintenance referred to as a tool of western administration has been blamed by critics as doing little to improve the government's or other organisations's capacity to innovate and experiment (Rondinelli 1993, pp156).

A group of managers of African descent who were certified agricultural supervisors succeeded these white managers. These cadres were first recruited when the water management of irrigation schemes was still under DERUDE. They were - in most cases - above average performers who displayed a considerable degree of commitment to duty. When the merger with Agritex came they were assimilated into the Agritex structures and re-graded as extension supervisors.

In this way a structural problem was created and its resolution has haunted the management of irrigation schemes ever since. These managers were initially requested to report directly to the District Agricultural Extension Officer (DAEO). There were problems of accountability at some schemes with some extension officers at Nyanyadzi, for example, finding this arrangement untenable. The same problem surfaced amongst officers at Nyamaropa and Chibuwe. The extension officers by virtue of their higher educational qualifications i.e. degrees or diploma did not find it acceptable that managers with certificates

[4] Zawe (personal communication) notes that the title 'extension worker' came after independence, as it was felt a better name. However, even today they may still be expected to work like demonstrators. Leeuwis explores the preferred changes within extension science (see Leeuwis in Moll and Manzungu, 2003)

had the same responsibility to report to the district officer as they did. They are understood to have influenced the district officers to press the provincial agricultural officer (field) to recommend the downgrading of the irrigation managers' duties.[5] The move to downgrade the irrigation managers got a sympathetic response from the then irrigation divisional head.

The irrigation division of Derude at the time of merger retained the deputy director post in the new department. Eventually the incumbent also became Director of Agritex. The irrigation section was downgraded to a branch under what became known as the engineering division. Most officers from Derude who were field-based were re-graded into Officer II for diploma holders and Irrigation Specialists for those who held degrees. Those that were scheme-based were re-deployed at provincial level although later some found their way back to the districts. The major problem was that Derude irrigation managers were graded higher than their colleagues with similar academic qualifications in Conex. This meant that certificate holders were to be remunerated at the same level as diploma holders. This situation was consistent with the administrative responsibilities given to these individuals under local government structures. However, it was not a tenable situation under the new Agritex structure. It was decided to abolish the post of irrigation manager. Sitting managers were re-categorised as extension supervisors. They, therefore, fell "squarely" under the area extension officer.

In terms of agricultural roles - advising farmers on what crops to grow and the best rotations and fertilisers to use - this was a satisfactory arrangement. However, the social, financial and organisational issues that distinguish a smallholder irrigation scheme from an individual producer were not addressed. The reasons for placing new irrigation schemes under local government structures were never revisited. It is possible that only the negative aspects of the 'despotic' management control of production before the changes were highlighted and the care that had been taken over irrigation water supply remained unacknowledged. While the Rhodesian legislation compelled farmers to follow the plans of irrigation managers for their cropping, it also used simple technologies that made it easier for farmers to assist in irrigation management even though there were elements of compulsion. The new technologies, however, have a substantial capital requirement for both operation and maintenance meaning that it is insufficient simply to compel farmers to assist. They must also have good technical specifications and adequate skills and resources.

The DAEO's and EO's started going to schemes to impose their new-found control over the irrigation managers. They took assets and vehicles and whatever they found convenient to the district offices as a form of rationalisation of resources. Any form of resistance resulted in the irrigation managers being asked to conform or resign. Soon, few maintenance facilities and tools remained in schemes and sometimes these had to be built up again through new special assistance projects. The poor control of irrigation assets led to accountability problems, accusations of theft and patronage.

One of the authors worked with the first group of African managers in Manicaland, and later tracked their fate. Most of them were old and in a short time the managers of Nyamaropa, Nyanyadzi, Mutema and Chibuwe had left the department. Mr. A., ex-manager in Nyanyadzi, is now a *mutape* (headman) in his home area on the Mutema irrigation system, where he uses his knowledge and experience for farmers. The situation was not so easy for the younger irrigation managers. Mr B stayed on at Deure and was appointed to the

[5] This PAEO (F) for Manicaland was later promoted to chief. He was later engaged as a training co-ordinator for the SSIP programme that tried hard to rethink local management and enhance capabilities for O&M. One hopes that he appreciated the missing or weakened administrative structure that is now being championed in irrigation management transfer (IMT).

construction unit supported by the SHIP[6] project and later transferred to a dryland area in Buhera. Mr. C from Matabeleland joined the Agritex head office and retrained as a cartographer. This individual recently took up the post of Chief planning technician in the new department of irrigation in MRRWD.

Irrigation Management Committees

The first acknowledgement of the need for links with farmers began with the recognition of farmers' representatives. The government officials who managed the schemes were mainly whites. They found it difficult to resolve conflicts between the farmers without a proper understanding of their culture. They also wanted people who could inform them of the things that went on within the local community. They wanted a clear understanding of the response of the society to some of their management initiatives. Therefore, one can say representatives acted as a feedback mechanism. The farmers in part liked the system because they could influence the management because they had the opportunity to convince the people responsible for particular tasks. The system worked well when there was no cause for concern. When controversies arose, however, the position of farmer representatives could become untenable as they would find themselves in a sort of broker position. The management would then ensure that the representatives were loyal to them. Those that were not loyal were replaced. This situation deteriorated during the liberation war. The representatives were inevitably labelled sell-outs because they were loyal to white management and farmer representation almost collapsed ((Magadlela, 2000). At a collective level, there was also a move to create marketing co-operatives, but these organisations also became targets during the liberation struggle (Zawe, 2000, Pazvakavambwa, 1995).

The concept of the Irrigation Management Committees was raised in the DERUDE's 1983 'irrigation policy' paper. One of major objectives of the proposed policy paper was to try to fill this vacuum left by the disappearance of representatives. It proposed the establishment of irrigation management committees, as operational entities and to correct the negative image of farmer representatives. A lot of effort was, therefore, put into ensuring that new irrigation management committees were elected and that the selection process was made more democratic. Not surprisingly, many aspects of local economic and political power play came into these committees (Magadlela, 2000). The process itself cannot be more advanced than the general political maturity of the society that practices it. Therefore, in some schemes the irrigation management committees have established sound working arrangements that allow open canvassing and campaigning as reported in Nyamaropa, one of the older farmer-managed systems (Magadlela, 2000).

However, while the 1983 paper introduced the concept of water users associations in Zimbabwe, there was little subsequent effort to rethink the practicalities of the local operational management in which they were situated. This lack of capacity to act well in operation and maintenance has reduced many IMC to handling disciplinary issues only. In systems with Agritex management, they remain in effect a disciplinary arm ranked under the Extension Officer, enforcing bylaws, and involved in crop planning alongside Agritex extension staff. There is no available document that shows that the issue was ever followed up after the DERUDE 1983 proposal. What effectively happened, therefore, was the erosion of the irrigation managers' authority and power even before their post disappeared by creating in the mind of low-ranking government officials and farmers a mind set that a new institution had been formed. However, the real powers and duties of this institution – the IMC - remained unclear.

[6] SHIP was a donor-financed project that provided construction equipment for rehabilitation and new projects in the late 1990s.

In some schemes, the IMC's have become a powerful lobby for farmers' rights and resources. However, in others, their disciplinary control is not tight enough as observed in the by-law situation. They miss the very first requirement - the recognition and authorisation that allows them to issue by-laws. A number of enthusiastic IMCs have been frustrated by members who are aware of this weakness and who therefore choose to ignore the by-laws. When the irrigation branch of Agritex was formed, the issue of new institutions and organisational structures in irrigation was considered to be of direct personal concern to the power of the senior staff. Thus the IMCs formed at the old schemes never got the legal status and administrative authority that was exercised by the irrigation manager and the District Commissioner[7]. The extension staff in the schemes are still attempting to work with this arrangement. One major bottleneck here is the question of the power to revise maintenance fees.

The authority problems of the IMCs have been made worse by the growth of 'illegal gardens' alongside conveyance canals and water being taken to maintain them. The problem of illegal gardens is site specific. Long conveyance canals that pass through residential areas tend to have more severe problems. These problems are dynamic and can develop with the age of the scheme. Communal schemes tend to be more affected by this problem because of higher population densities in the watersheds crossed by canals. The authority of the IMC can also be challenged inside irrigated areas, as powerful farmers take up cultivation in the irrigation drains and even 'block off' parts of canals. The original irrigation managers took severe action again illegal encroachment and burnt illegal gardens. Solutions to the "illegal gardens" problems have varied but it remains difficult to legislate and enforce rules to deal effectively with the situation. The IMC have no jurisdiction over the non-registered 'outsiders'. This problem can sometimes be managed with the co-operation of local authorities. Technological interventions, which include piping, constructing canals in cut where possible and covering canal sections, are not universally applicable. Small schemes with inherent water scarcity tend to feel the effects more.

As interest in local management grew among donors and later Agritex staff, the IMC was expected to play a leading role in compiling scheme requirements and ensuring that tasks were executed as planned. They were expected to take the lead in determining the level of contribution each farmer was expected to pay towards the maintenance fund. By adopting this approach it was hoped that the IMC would eventually take responsibility for maintenance and other improvement works. This was in line with the FAO recommendations (Vermillion and Sagardoy/FAO, 1999). The operation and management team of the irrigation branch spearheaded this drive[8]. However, it later came under threat from the call for general subsidies to the IMCs because these were facing the growing problem of trying to meet continually increasing electricity and operational costs. In 1994, Agritex still appeared to reject the ideas of regular targeted subsidies, but allowed 'special case exceptions' (often for more problematic schemes like Bonde where Agritex itself was responsible for expensive operating systems). This has made it difficult to find clear future directions for local management responsibility and action.

[7] The IMC still have no formal office or status at the schemes administration establishment. At best they have been offered an office with no facilities or secretarial staff. The IMC at most schemes hold their meetings outside. Minutes of their meetings do not get filed within Agritex files.

[8] In the period 1994 to 2001 the irrigation branch especially at head office were organised into clusters or teams that looked at three areas namely: (1) research, testing and training, (2) planning and development and (3) operation and maintenance of schemes. The objective was to ensure that all relevant irrigation issues got attention.

" It is policy that in future, costs of operation and maintenance of irrigation systems be met directly by beneficiaries. Any subsidies on O&M costs should be justified and targeted on a case by case basis" (Zimbabwe 1994).

More recently, Agritex also discussed possibilities for 'cost-sharing' of water and electricity charges with irrigators. Thus, it continued to show a lack of clarity in its role towards smallholder irrigation and irrigators. The question remains unanswered of whether systems should survive as profitable locally managed schemes, or be subsidised schemes more concerned with wider livelihood support as the original older schemes were constructed. The success of IMC's in meeting these financial challenges has been varied and ranges from those who still look to government to sustain their operation to those who have found a suitable business arrangement that sustains production and cover costs. Thus we can see different 'coping strategies' by farmers and IMCs. Some diversify into horticulture as a profitable farming strategy neglecting other crop guidelines and often only using the irrigation system for part of the year. Others persist in asking for government assistance. Yet others (see Section 4) make dangerous forays and make use of private banking facilities to raise money, risking their irrigation equipment in the process.

Recognising the situation in 2001, Agritex noted:
"The policy (has been) of total responsibility for O & M costs by the farmers with government only providing technical and extension services. The result has been a total breakdown of good crop cultural practices such as block farming and rotations as farmers try to grow anything that will help them meet the scheme operating costs. This has led to mono-cropping with those crops that are seen to be giving good margins" (Agritex, 2001).

Such observations are widely reported by researchers and consultants (Manzungu and van der Zaag, 1996; Pazvakavambwa, 1995). Several externally-funded programmes have evolved to try and develop the skills of the IMCs. The Small-Scale Irrigation Scheme Project begun in 1987 under FAO later came to make proposals for training after an initially stronger focus on technical issues. In the DANIDA Smallholder Irrigation Support Programmes (SISP) the issue of training has been given considerable emphasis. There has been a proposal for an Irrigation Act that make the responsibilities of management much clearer (Pazvakavambwa, 1995). However, clear guidelines are still lacking for IMCs on the financial tasks and collection options available to them for raising money and managing fees.

Fees and the payment of electricity, operation and capital costs
Irrigation charges began around 1970, under the permit charge regulations in the 'Control of Irrigable Areas Regulations". District Commissioners saw them as way of ensuring performance and as a cost recovery mechanism. DERUDE first introduced a maintenance fee (which Agritex simply adopted), but it never formally institutionalised it as a charging system. In 1983, the maintenance fee was ZIM$145 and it has remained at that level ever since. The lack of clarity over authority to levy or collect fees meant there was no facility to review these fees. One excuse initially used was that because these fees went to treasury the department and farmers had no motivation to ensure that they were paid. This section gives a brief review of the fate of fee payment during the recent period of institutional change.

Under the Rhodesian regime farmers were compelled to assist with maintenance and pay **water rates** by a stipulated date. The scheme clerk or another member of the administrative staff collects the **maintenance fees** at government-managed schemes. Today, the scheme clerks report administratively to the senior extension officer responsible for a particular station. These individuals report financially to the provincial head of administration.

Instead of re-visiting this irrigation fee to recognise service to farmers or considering what technical assistance was needed to support irrigation, a new concept of farmer management was proposed and applied - the IMCs. This concept has taken the payment of operational costs from government to the farmers, but it has defined neither what farmers should pay nor the services that can be supplied.

The DWD has also had a structure of water charges, as well as charges for different operational services. During the 1970s, during construction of new dams user departments were charged for water from old dams like the Ruti and were charged two costs. One was for dam maintenance. This was a long-term recurrent cost based on the staffing and activities required for the maintenance of the hydraulic integrity and water delivery of the structure. The other charge related to the capital redemption associated with financing the structure. These costs for the Ruti dam were charged to Agritex and ARDA. In theory this meant that the dam should have become the property of these two organisations with the DWD as managing agency. This changed later, however, and a blended pricing system was introduced. This in theory would price all water from all dams at the same cost. The advantage would be that cheaper water from old dams would offset the higher costs of newer and hydraulically less efficient storages. Costing was worked out by DWD. Time and volume specific water permits were issued by the Ministry of Agriculture Irrigation Development (MAID) committee, later chaired by Agritex and with advice from the provincial water engineer of the source in question.

The cost of water stayed at Zim$44 per mega litre of water throughout the 1980s and 1990s, but the charge was raised to Zim$350 by ZINWA in 2001. For this review, ZINWA probably took into account calls from agricultural policy makers to price water in a way that reflected its scarcity[9] as suggested in the ZAPF and draft irrigation policy document of 1994. Economists also advised that concepts of long-term marginal costing be adopted. The new charge was a shock to Agritex who asserted that farmers would not be able to pay such high costs[10]. However, while treated as a big increase by many, in fact the new fee is worth less than the fee of Zim$44 in 1977 if inflation is taken into account.

Subsidies on electricity costs have also been discussed and one suggestion has been that the new water charges should be halved, with a further charge related to a special tariff for those pumping this water. What is the present situation in lift irrigation systems operated by expensive pumps? In 2000, all new schemes were required to register themselves as clients of the electricity power service within a period of two cropping seasons. Prior to this Agritex was the registered electricity consumer and this implied that the organisation had a duty to monitor and ensure that all schemes were paying charges so the government would not be put in the position of accruing unmanaged debt. Those schemes that used diesel bought their own fuel. In older schemes the situation has not yet been standardised. In Manicaland the transfer

[9] "*Water pricing policy in future should reflect the scarcity of this valuable commodity. The price of water, therefore should take its opportunity cost into consideration in order to arrest its wastage and inefficient use…..It is policy that in future, costs of operation and maintenance of irrigation systems be met directly by beneficiaries. Any subsidies on O & M costs should be justified and targeted on a case by case basis*," (Zimbabwe, 1994)

[10] "*The unmanageable water charges which are being levied on all types of water i.e.storage, flow and groundwater…. This figure has risen from as low as Z$44 per ML in 1997 to the current Z$310/ML. This is an increase of about 600% within three years. This price is just too high for the farmers…..Extremely high charges by ZESA are stifling the efforts by government to develop and improve the performance of the smallholder irrigation sector, although the large scale has not been spared either…..Government should therefore: enter into a 50 – 50 cost sharing arrangement with all the irrigators for the energy and water charges i.e. reduce the water charges to Z$155 per Megalitre and institute a special electricity tariff for agriculture which would be affordable to farmers*" (Agritex, 2001).

of energy bills to IMC's started after the commissioning of Musikavanhu and Bonde. With these new arrangements, farmers in other older pumping schemes found that they were 'cornered'. Some faced these problems head-on; others were more opportunist and looked for other sources of funds to pay their power bills.

In this respect, older irrigation workers and Ministry personnel who have moved between systems often play important roles in mediating between the public institutions that still hold financial power over O&M funding. In one scheme in Mashonaland West a pump operator who was also an irrigator proved to be a major actor in the question of electricity payments. He is understood to have influenced farmers to opt for letting DWD take over the payment of electricity. It was only when a DWD official cut off the water supply to the scheme and also stated that the scheme would close down if farmers expected DWD to pay for electricity that the farmers started negotiating with Agritex. Eventually, they managed to get the entire electricity bill paid by Agritex for that period only. The farmers in this scheme are now gearing themselves to pay electricity on a sustained basis. However the power utility is now openly advocating that consumers pay their bills in foreign currency due to the shortages of hard currency that the country is going through.

The new look ZINWA still seems to follow old ways with fees and service contracts very much along the lines suggested by DWD in the 1970s despite the scepticism of some farmers and Agritex itself. As far as the maintenance of pumping units is concerned, the new order says that farmers should turn to irrigation companies to meet their service needs. This has worked well for small schemes of 50 ha or less or those with small pump modules. Spares are, in most cases, stock items at irrigation companies and fees for repairs are easily quoted. Farmers can take the pump units to repair shops on their own and sometimes they can even fit the spares themselves. Pumps can be transported using ordinary public transport or by employing small pick-up trucks.

This is not the case where larger pumps such as those at Bonde are concerned. The DWD has retained repair and maintenance functions. The farmers carry out repair and maintenance on the booster units that have smaller modules. However, in both cases, workshops for repair works are outside the irrigation schemes.

How can Agritex continue to support irrigation systems when it is itself affected by financial cuts under structural adjustment programmes? Agritex participates in the Agricultural Revolving Fund (ARF)[11] instituted by the Ministry of Finance and the Ministry of Lands and Agriculture. The maintenance fees from irrigation schemes are now being deposited in the ARF account instead of being remitted to central revenue. The farmers and IMCs, through their provincial and district offices, are required to come up with a work programme for using funds in their individual schemes. They are also required to revise the amount of money contributed to individual schemes depending on perceived maintenance requirements. This arrangement has focused on the financial capability of Agritex personnel rather than on the IMCs. Agritex personnel on each scheme need to be technically and financial able to define maintenance needs and convert these into technical work. This can

[11] The ARF is a pilot programme in 1999 launched by the Ministry of Finance and Ministry of Lands and Agriculture. It is aimed at building capacity in government's institutions to run 'suspense accounts'. This essentially means the institutions participating in this facility have opportunities to directly generate income from various activities. They can then also use the revenue so generated to finance their activities. This is different from the normal expenditure accounting that Agritex and other government institutions were used to. It can have far reaching positive effects on building capacity of the institution to spearhead IMT in future. However, critics assert it just assists the department to fund itself, not to finance the operations of clients, and that if specialists charge for services rendered, then plough back the money, they need not be charging in the first place. Also, critics say it is just a means to cover travel and subsistence allowances for senior staff. This shows how ideas can get corrupted.

then be costed and implemented, monitored, audited and evaluated. This is not an easy procedure for local staff. The financial training of Agritex accounts staff starts by focusing on head office and provinces. Few scheme clerks have been exposed to the requirements of the "new look accountant". There is even less training in these areas for members of the IMCs.

Thus in their price reviews, Agritex adopted an inconsistent position, sometimes saying IMC's and farmers should pay all operational costs, but sometimes also suggesting general subsidies and subsidised tariffs to help farmers situated in irrigation schemes with high operating costs. What remains in Zimbabwe are many rhetorical statements both about the importance of local action in covering local operational needs and resolving charges for water. But there are still no really clear guidelines or support measures. The DWD and Agritex interlock in the supply of water, but have very different ideas and attitudes towards the IMC organisation itself and the type of support that should be given to farmers. What remains are a series of mixed responsibilities for different areas of operational irrigation management and these even differ from scheme to scheme. There is talk about and experimentation with innovation. However, innovation stress remains real.

This section ends with table 2.3.1 showing the various responsibilities for different aspects of operations and maintenance in different irrigation schemes. New reforms not only have to restore viability to operations and maintenance arrangements - they also have to ensure that more attention is given to these aspects in irrigation design. Responsibilities have to be clarified between institutions, and inconsistencies removed in how different schemes meet their costs and undertake their management responsibilities.

Table 2.3.1 Examples of institutional responsibilities with Agritex. DWD or farmers in selected pump lift irrigation schemes in year 2000.

Scheme name & Size	Province	Head (m)	Application method	Agency responsible				
				Water charges	Energy costs	Mainte nance	Operatio nal staff	Coping strategy
Ngezi 200 ha	Mash.West	80	Sp-drg	farmer	Agritex	DWD	DWD	Govt.asst
Negomo 250 ha	Mash.Cent.	60	Sp-drg	Not yet	Agritex	DWD	DWD	Govt asst.
Princippe 50 ha	Mash.Cent.	60	Sp-drg	Not yet	farmer	farmer	Farmer	Hort.
Chitora 10 ha	Mash.East	60	Sp-drg	Not yet	farmer	farmer	Farmer	Hort.
Nyandoro	Mash.East	60	Sp-drg	Not yet	Farmer	farmer	Farmer	Hort.
Wenimbi 10 ha	Mash.East	60	Sp-drg	Not yet	Farmer	farmer	Farmer	Hort.
Hama Mavhaire 30 ha	Midlands	70	Sp-drg	Farmer	DWD	DWD	DWD	Govt asst.
Insukamini 30 ha	Midlands	60	Sp-con	Farmer	DWD	DWD	DWD	Govt asst.
Mayorca 110 ha	Midlands	110	Sp-drg	Not yet	Farmer	farmer	Farmer	Govt asst.
Makwe 30 ha	Mat.South	30	Surfac	Farmer	DWD	DWD	DWD	Govt asst.
Valley 200 ha	Mat.South	110	Sp-drg	Farmer	DWD	DWD	DWD	Govt asst.
Chilonga 90 ha	Masvingo	30	Surface	Farmer	DWD	DWD	DWD	Govt asst.

Longdale 10 ha	Masvingo	60	Sp-drg	Farmer	Farmer	farmer	Farmer	Down
Mabvute 50 ha	Masvingo	40	Surface	Farmer	DWD	DWD	DWD	Govt asst.
Mutema 180 ha	Manicaland	85	Sp-con	Not yet	Agritex & farmer	DWD	DWD	Half down
Bonde 260 ha	Manicaland	120	Sp-drg	Not yet	Agritex & farmer	DWD	DWD	Half down
Musikavanhu 800 ha	Manicaland	25	Surface	Not yet	Farmer	farmer not yet	Farmer-hired	Searching
Nyakomba 460 ha	Manicaland	80	Surface	Not yet	Farmer	DWD	DWD	Search & hort.
Nenhowe 120 ha	Manicaland	50	Surface	Not yet	Farmer	DWD	DWD	Down half of year

Irrigation application method: sp-drg – sprinkler draghose, sp-con – sprinkler with laterals
Coping strategy: Govt.asst – government subsidy, hort – market-oriented horticulture

2.4 THE OLD AND THE NEW IN OPERATIONS AND MAINTENANCE

Equipment and manpower

The old schemes, (Chakowa, Deure and Mutema in this study) had some compliments of maintenance personnel. They have been left to decline since the 1987 merger under the guise of promoting farmer management. Chakowa had a ten men maintenance team before independence. Now it has three. The maintenance gang had a special place for water distribution staff known locally as water bailiffs. The post of bailiff has been maintained even in systems where the size of the maintenance team has been cut, and bailiffs work closely with extension workers[12]. The new schemes (Musikavanhu, Bonde and Mpudzi in this study) do not have any government operators. After an initial project-supported phase of about two years, the farmers were expected to start paying operators previously paid by the project and Agritex. For example, at Musikavanhu, farmers did not like this and they devised their own salary norms for operators, which include a salary scheme with a lower cash income but the right to cultivate a garden around the pump house. The operators did not like this but had no way of redressing the situation because they have neither a document setting out conditions of service neither nor any proof of employment.

The technical inventories of old schemes show that in the old schemes transport including lorries, trucks and tractors were provided for the gangs. Other equipment and accessories were also provided. The old managers and supervisors were able to effectively repair and maintain the whole irrigation delivery system and its accessories. The delivery system for a scheme like Deure comprised the intake weir, the earth supply canal and the distributary and tertiary canal. Support structures for this delivery system comprised the road to the intake, roads running parallel to the supply canal and distributary canal, the drainage network and structures as well as bridges and overchutes. Control and measurement or regulation structures like gates and flumes were also included. The assortment of vehicles, building equipment, spares, shovels, dam scoops and tractor-drawn land planes all facilitated the speedy and timely maintenance of infrastructure. Stocks of slashers, picks, shovels, machetes, hoes, hard brooms and other pieces of equipment were required to cleaning the canals.

A programme of molusciding by personnel known as snail rangers was also in place to reduce the danger of farmers and maintenance crew contracting bilharzia. However, the older

[12] In 2002, Bailiffs and maintenance staff were transferred to the new Ministry of Rural Resources and Water Development.

equipment inventories and institutionalised cleaning programmes are in decline. At Deure, for example, the drum of moluscide was in the storeroom but the local staff did not know what it was for or when and how to use it. They had no experience or training in this procedure. The current poor maintenance of workshops and spares at government storerooms leaves no facility for training the officers who should train the farmers.

The technical inventories for the new schemes - both surface and overhead - show that even in large new schemes like Musikavanhu there is no provision for transport, telephone and mail services. The two blocks of 400 ha each have no lorry, truck or tractor to move the material and people needed to carry out repair work both within and outside the scheme.

The only scheme that had maintenance equipment after independence was the Nyakomba scheme. This scheme was developed as a pilot model of a fully equipped scheme that could provide training and maintenance services. In Nyakomba a full complement of equipment including a lorry, truck, tractors, bicycles and other material was available. The scheme also had office and storeroom facilities to cater for farmers, Agritex extension agents and the DWD pump operators. However, the important question of who will employ the maintenance gang remains unresolved on this scheme as well.

New training for O&M

It has been proposed that facilities similar to those at Nyakomba be made available at other locations as well. Farmers can then be trained to provide labour, money, or give contribution in kind to ensure that the scheme is maintained. However, it is even more important that farmers and extension staff to be trained in the management of local staff and works – in the diverse aspects of recruitment, employment, work planning, supervision, and remuneration of local service providers. Staff training should be accompanied by establishing conditions of service. This is a high level responsibility and can only be successfully carried out in highly qualified, highly motivated, educated and well-resourced irrigation committees. The different communities and their irrigation organisations in smallholder irrigation in Zimbabwe have not been assessed for their capacity to take on this type of responsibility. This ought to be the very first task undertaken in each scheme whether it is new or old, before popular phrases like 'farmer management' are used. For example, in Musikavanhu, people have engaged in training programmes that do not have clearly defined objectives in terms of technology care, although fear over how to sustain the borehole pumps tops the list of concerns. A clear practical programme of O&M was never developed by the team of consultants present in Musikavanhu despite three years of work that ended in year 2003. Water bailiffs on government schemes have always been recruited from amongst the general maintenance staff. While in operational terms this is a demanding job it has never received recognition. Therefore, for most schemes training merely involves attachment to another water bailiff for a period that can range from a week to a month. Members of the local extension services try to make their own training arrangements to fill in the gaps. In farmer-managed irrigation systems, farmers chose water bailiffs from among themselves. However, at schemes like Deure where the government has always provided water bailiffs, farmers cannot imagine a situation where farmers allocate water to themselves.

In most government-managed irrigation systems DWD personnel operate pumps. The DWD trained its pump operators better in our view compared to Agritex. It is understood that they normally train under a technician. They can then be recommended to take care of sites as the opportunity arise. This approach is different from the Agritex approach. In general the responsibility, record keeping and maintenance level seems to be higher at sites run by DWD pump operators. Another factor that might influence performance is the fact that DWD operators are fully employed and accountable to the institution.

Agritex does not have an establishment post for pump operators: in all its pumped schemes farmers (or operators appointed by the IMC) operate the pumps. In the majority of these schemes - which are mostly small-scale - ordinary farmers are either specially chosen or they simply rotate the task. The equipment supplier should provide the first technical training for pump operators in line with the irrigation branch recommendation. Agritex provides the other training courses. Recently the Zimbabwe Irrigation Technology Centre (ZITC), which is the research and testing wing of the irrigation branch, launched a pump operator's course. It has not been possible to get operators at most schemes to attend the course as either no funds are present or they cannot leave their posts. The farmers and operators at Musikavanhu had a course run for them locally in the year 2000. In larger farmer-managed schemes like Musikavanhu and Bonde, Agritex does not have a direct relationship with either the operators in the former or booster pump operators in the latter. The pump operators are accountable to the farmers.

For the new small schemes, two or three days training from the equipment supplier is considered enough. Farmers are obliged to sign on as contract labour so they can learn about their system and be trained on it. Contractors have responded positively to this. Some spares can be provided to demonstrate the working of pumps, motors, pipelines and fittings. This was assumed to be enough for schemes to be self-sustaining. The training offered usually consists of demonstrating how the equipment should be started. No manuals for further use, guidelines for service, or recommended spares and where to buy them are provided. The DAEO for Chipinge and the new DAEO for Buhera were interviewed separately in January 2001 to find out how much they knew about their schemes. Both of them acknowledged that they were not fully aware of the O&M status and requirements of irrigation schemes in their district as detailed in chapter 4 and 6.

The DAEOs expected new projects to fund and provide relevant facilities for training and subsequent record keeping. The projects, on the other hand, expected the DAEOs - being the extension heads - to ask for the facilities needed to make advisory services available. In the feasibility studies these systems are supposed to be commercially viable enterprises: yet these schemes show that little basic facilities or training are available to demonstrate this. The public financing system requires one to obtain an authentic quotation before funds can be committed to repairs or replacements. In 2000, the farmers at Principe say they damaged their submersible pump in an attempt to repair it. Despite taking it to Harare and Bulawayo it was beyond repair. They were only able to pay half the costs of this quest. The other half came from government assistance.

It is rare for new schemes to have structures and operational routines that allow system performance to be monitored as part of an accountability procedure for management and water use. All blocks of Musikavanhu have different operating arrangements and these range from using farmers themselves to employing a "worker". The net result is that no operating records have been kept, nor is there anyone to file them. The same applies to Bonde pumping records. Nobody knows whether the records are being collected or not. There is no analysis of the way equipment is used, or of power consumption or water use. The very benefits that sprinkler systems are supposed to show are not being recorded formally. This situation was also allowed to happen at Mutema. No purposeful data collection system had been initiated, meaning there is no information on supposed advantages and durability of sprinklers and pressurised systems. If such comparisons are to be made a system of purposeful data collection, analysis and information generation and dissemination must be set up.

Irrigation equipment donated for scheme construction is also often difficult to account for. The field division considered these assets the property of the CAEO in his province with no room for national deployment. Plant including bulldozers and graders could be standing idle in one province while another province is desperately trying to hire similar machines. The implementers of system plans often prefer to hire equipment in order to avoid questions of ownership. Farmers now recognise the importance of equipment. In Nyakomba they requested access to a tractor donated by the Japanese Government to the Government of Zimbabwe. Their rationale was that they took part in the handover ceremony - and therefore the bulldozer/truck, tractor and lorry was theirs - and they could use it to plough their field and to ferry produce home and to markets.

The smallholder irrigation support programme (SISP) funded by DANIDA and IFAD gave a new twist to the need to define the role and powers of the institution responsible for an irrigation scheme. An appraisal found it necessary to re-examine the role of local government in the management of irrigation schemes as existed with Devag and DERUDE in the 1980's. This was not well received by the then management of Agritex, which was not surprising since they had been trying to push aside the irrigation manager issue. The SISP tried to find how participatory and financial concerns could be effectively tackled with the involvement of local government. Facilitators for this programme were recruited and placed under the provincial administrator's office, while the SISP coordinator was housed under Agritex. However, the 2001 project review carried out by the financiers and government of Zimbabwe did not find any reason for working with local government structures, and recommended that the program stay under the Deputy Director Engineering in Agritex.

Fee payment and its use in maintenance

As discussed earlier, maintenance fees cannot be revised because the procedures and authority to do this have never been considered. Meanwhile the collection rate has become even more problematic and the cost of fee collection can be significantly higher than the fees collected. It is the new schemes that have received the most attention as far as transferring operating responsibility to farmers is concerned. There were many initial successes in small schemes especially those growing horticulture crops around Harare. This initial success was followed by a rapid expansion into bigger and more schemes. However, in all these new schemes farmers only paid operating costs [13]. There was no mention or provision for maintenance costs. The resulting lack of maintenance, therefore, put farmer-managed schemes on par with their counterparts in older 'government-managed schemes' who only pay token fees. While IMC's have taken up collecting fees for operational costs, there is no proper accounting system for the fees collected. This means that the old and new schemes are quite similar as far as maintenance and replacement scenarios are concerned, and all farmers are now coming back to the government for rehabilitation. Yet economic feasibility studies clearly indicated the viability of these new enterprises based on standard FIRR and EIRR criteria. Apparently, irrigation plans did take account of the maintenance and replacement requirements, and took no responsibility for providing any practical operationalization of maintenance.

Assumptions were made that the IMT process would automatically create its own responsible cadre who would then develop the necessary administrative, financial and legal structures to take care of infrastructure sustainability. When this did not work, the recourse was to ask government to intervene to offset increases in electricity and water charges.

Agritex has been using government funds provided under the public sector investment program to maintain schemes. The schemes, provinces and head office make costings to meet the maintenance required for each scheme. Funds are provided as a lump sum and are subsequently parcelled out to the provinces. A scheme invariably gets less than asked for. Therefore, there was leverage for head office to decide and rationalise. With the increasing failure of pumped schemes and the pressure to keep them running, this task has become more

[13] In reality they only pay energy costs. As already explained they are reluctant to pay the operators.

and more complicated. A rather unfair proportion seems to be going towards the pumped sprinkler schemes where operational costs top the list. However, both government-managed and farmer-managed systems require assistance. One administrator once asked why an FMIS should be assisted when it does not even pay a token maintenance fee. This was a frightening question.

Recently, clerks stationed at government run irrigation schemes have been subjected to a lot of training under the current Agricultural Services Management Program (ASMP). However, they still have to be exposed to the use of suspense accounts, and the wider complexities of government funding that might pay towards their operation and maintenance needs. Up to now their experience has mainly been with expenditure accounts. With the proposed devolution of responsibility to the schemes - as stated in the 1994 policy document - there are plans to involve these cadres both in collecting funds for operation and maintenance and in using these funds for planned works at the schemes. The finances are to be accounted for by work under the ARF (see footnote 10).

The maintenance situation seems to be a lot worse in the FMIS facing financial stresses in O&M. As already discussed there are no public accounting structures. The farmers, therefore, often call for funds as and when an emergency arises. In the event that they fail to get funds together, they simply get by with what they have - or they enter into financial deals that can backfire. A scheme in Mutoko went too far with such deals and put its public-funded sprinkler irrigation system up as collateral to raise money. It had debts with Zesa, AFC, Zimbank as well as with other entrepreneurs. The bank, realizing that the farmers had used the irrigation equipment as collateral, moved in after protracted efforts to get a settlement and got the equipment to the auctioneers. The farmers finally came to Agritex to report the situation and ask for help. However, the hammer had already fallen. The fact that there are a large number of pumped sprinkler schemes that have run into the same problem or simply fall into decay gives reason for concern. Two options present themselves. The first is to get these schemes back urgently onto the public accountants audit list. The second is to ask those managing them to prove their competence by means of a transparent audit.

As argued here, technological care is increasingly being delegated under the concept of farmer management, not only for the development of the water delivery and distribution infrastructure but also to provide services for the operation and maintenance of infrastructure. Until 2002, Agritex as an institution did not have the capacity to source alternative transport from the private sector to visit schemes.

2.5 CONCLUSIONS

"*The above problems have resulted in irrigation schemes that are decaying and dying all over the country. The multi-billion investment by government since independence is going to waste unless something is done and done urgently to reverse the situation*" (Agritex, 2001).

This paper shows how gaps and weaknesses in institutional interfaces at local, regional and state level have failed to provide either a base for reflection and coherent learning about technology choices, or to put a support system in place for terotechnology - to care for this technology. Instead irrigation service institutions show a technological repertoire heavily influenced by international donor preferences and scientific debates - and little capacity to look coherently at what makes a whole irrigation system work. Forced innovation has been a critical feature in the fate of smallholder irrigation management in Zimbabwe. There have indeed been many attempts to innovate but usually as interventions for technical and institutional streamlining rather than 'making systems work'. There has been a shift of thinking that has led to a system of irrigation manager, work gang and strong fee collection system being replaced by Irrigation Management Committee without formally defined powers. In this process little attention has been given to the issue of effective control or the effective provision of resources for O&M. Choices in technology have not been made with insight into institutional requirements or how they are to be maintained and kept working.

Before independence there was clarity in institutional domains and resources for O&M. and pump stations were under DWD. There has been a clear allocation of responsibility to Agritex for the operation and maintenance of canal systems. Agritex had success in developing small schemes and transferring them to farmer management, especially in Mashonaland. Agritex was aware that DWD did not have the capacity to create farmer institutions for pump management or to rectify problems at systems such as Bonde and Mutema. The DWD was aware that Agritex lacked the capacity for utilising stored water in dams. Now, both institutions find themselves with large pump schemes that neither government nor farmers can finance and there is a danger that these schemes will eventually collapse. The question of technological choice in a given environment seems to have been forgotten. There is a need to go back to the design table and not only debate technology choice but also study the institutions that can sustain the various technological options given local social needs, management capacity and the profitability of irrigation in the region. The interlocking institutions in irrigation and water management need to be made to work better amongst themselves and to improve their way of work with farmers. The case studies presented in chapter 3 to 8 are an initial attempt to understand these technological and institutional dynamics, and how local actors try to leverage irrigation supply in reality.

3 CHAKOWA[1]: RUN-OF-RIVER INTAKES WITH CROSSBLOCK DISTRIBUTION

3.1 INTRODUCTION

The first formal irrigation schemes to be developed by the state in Zimbabwe were run-of-river, gravity fed canal systems. Chakowa is one of the oldest schemes, with a weir intake founded on loose boundaries. The first weir was constructed in 1935 and started operating in 1936. Alvord identified the original weir site, prepared the original scheme layout and made demarcations for 5 blocks A-E. The first diversion weir and conveyance canal supplied water for irrigation of some land upstream of the main road and part of the current block A (45 ha). In the period up to the 1970's, the weir site was shifted downstream, 3 blocks B-D were developed (total 89.6 ha), and two night storage dams built to assist flow provision: plans for block E were abandoned. Before independence a white manager with a 15-member maintenance gang managed (controlled) the system: this is now down to 3 men. The initial smallholder irrigation system management was backed up by elaborate state machinery complete with control over farmers' cropping, residence and livestock management. The story of Chakowa is of farmers and managers struggling against decline.

Originally, farmers had to adhere to recommended cropping programmes. Plots were laid out as border strips for irrigation with siphons. Centrally marketed crops like maize, wheat and cotton were grown. Today maize is grown for subsistence, plus a range of crops are marketed locally with production options within the scheme shaped greatly by access to water and good soils.

The river intake supplies a surface irrigation system with gated control and rotational schedules. The earlier schemes in Zimbabwe were designed with simple gates only. The introduction of long weirs to regulate the division gates started only in the 1970's. Chakowa weir diverts perennial flow from the Umvumvumvu River, a tributary of the Save River, rising in the wetter humid cooler Eastern Highlands. However, the river has frequent high floods that shape the repair and maintenance requirements of diversion structures. It also faces low flows that decrease the reliability and predictability of the water supply and bring the challenges of scarcity into operations.

Chakowa thus presents several technologies from the core technological repertoire of Zimbabwean irrigation design, together with the original mechanisms of operation, maintenance and management control that made them work. These include:

- a diversion weir on loose foundations taking water from an unregulated river with extreme flow conditions
- cross block water distribution with a night storage dam
- long conveyance canals through areas without entitlements to irrigate
- border strip plots irrigated with siphons
- strict command area control with elimination of 'illegal' gardens.

Changes in infrastructure have been few since independence even after cyclone Eline. What has changed however, is the capacity for local control and thus of leverage to ensure resources and power to make the system work. Currently the Umvumvumvu remains un-regulated, although there have always been discussions about a dam, and two sites were identified.

[1] The farmers write the scheme name as Chakowa, as used in this thesis, but Makadho used Chakohwa (Makadho in Rukuni *op cit* 1994).

This chapter first presents the key elements of the scheme in its environment, and its changing WDSS and MSSS system. It then presents available performance data and flows with a description of the operation and maintenance challenges that shape performance. Chakowa has serious inequities in its cross-block distribution. The chapter then makes studies of operation and maintenance to explain this performance data and its impacts on local cooperation. It ends with a discussion of the leverage possible: it concludes the problems at Chakowa are a mixture of technological and social issues that need to be addressed together to find enduring solutions.

3.2 THE SCHEME AND ITS ENVIRONMENT

The Chakowa scheme lies along the Umvumvumvu River, a few kilometres upstream of its confluence with the Odzi River. Historically the upper cooler parts of the Umvumvumvu catchment was settled by white commercial farmers, and the Umvumvumvu valley also gets called the Cashel valley after a major farming and forestry enterprise upstream. The lower, hotter, less fertile parts, and the confluence zone, falls under the Mutambara Communal Land (formerly Mutambara Tribal Trust Land), which includes two smallholder irrigation schemes supplied by the Umvumvumvu, first Mutambara then Chakowa. Struggles for water supply between these two schemes led a former Member of Parliament (MP) to call for a stabilization structure in between the two schemes. Under the traditional local government structures the headman administers the affairs of the local community. There are two headmen in Chakowa. The head-end blocks A and B fall under headman Mutidzawanda. The downstream blocks C and D fall under the administration of headman Musiweshiri.

The Chakowa scheme is 70km from Mutare, the provincial capital of Manicaland. Mutare has a population of about 150000 people. This positions the scheme at the borderline of market-oriented production systems. The Mutare-Masvingo highway enhances this position. In practice therefore produce from neighbouring schemes are marketed at Chakowa. These include Mutambara and other smallholder schemes in Cashel valley like Mandima and Ruwaka as well as Mpudzi. A permanent vegetable market has been established specialising in core Chakowa crops like tomatoes, okra, onion, "green groundnuts", mango, sugar cane, bananas and green maize.

The Chakowa scheme has a ‘two-phase’ water right. It has a right from 1935 to take 60 l s^{-1} that was adequate for the first block developed. The permit was amended to allow extraction of 112 l s^{-1} *flow whenever available in the river* to allow for the current 90ha irrigated. There is one downstream user, such that the system also has to pass 4 l s^{-1} flow for this water right. Runoff and flow data has been measured since 1970 at the old Cashel Bridge gauging station E125 some 10 km upstream of Chakowa and immediately downstream of the Mutambara scheme. There are no major tributaries and water users between the gauging station and Chakowa irrigation scheme due to the rugged terrain. As there is no storage facility on the river, there is also a risk of shortage starting in March to November in years of poor rainfall as experienced in 1972/73 and 1982/83 culminating in periods of no flow as recorded in 1991/92.

The records also show that the high flood profile is characterised by a mean maximum flood of 316 $m^3 s^{-1}$ (February 1997). The floods records also show that there is an increase in the maximum mean and instantaneous flood discharge at Chakowa over the last 30 years. The magnitude of the flood due to the cyclone Eline is not yet available but it is expected to be much higher than this, as evidenced by the level of damage done to the weir. The river regime means that the scheme needs institutions to cope with water scarcity, and maintenance to deal with everyday siltation and episodic flood damage.

In its initial stages, the concern of Chakowa managers was on persuading locals to join the scheme. Local people were not interested in the scheme, as confirmed by one headman who himself went to work in South Africa 1938-1959[2]. Outsiders including some of Mozambican origin initially got irrigation plots. Some 'outsiders' also came from Cashel Forest where they had been chased away to make room for white commercial farms and forestry. This displacement by whites and resettlement is similar to that reported in Deure in chapter 4, and also in Nyamaropa (Magadlela, 1999). As the benefits became clear the issue of access was addressed through a formal waiting list, and eviction or rationalising of plots of poor performers to make way for new irrigators. With independence this practice stopped, due to its negative political implications. The net result was that any new aspirants had to access irrigation through "illegal" leasing or renting or "illegal" abstraction or gardening. The control of this practice occupied the greater part of the first black managers of smallholder irrigation schemes. Sometimes they took part in burning of these "illegal" gardens and had to answer in courts of law.

Plot size in Chakowa varies from 0.4 to 1.6 ha with an average of 0.8ha. This reflects the colonial management approach where above average performers were given opportunities to increase plot sizes and those below average had plots reduced and given to either new irrigators or those performing above average as elaborated in section 3.4 (and also reported at Nyamaropa, see Magadlela 1999). However 0.4 ha units emerged, that were generally created to cater only for those joining the scheme late or poor performers. However this practice was widely condemned and politicised. There has been no plot size rationalisation directly involving government officials since Zimbabwe's independence in 1980. Most of plot allocation issues are being left to the traditional and customary leadership structures. To date a lot of contestation emanates from grievances centred on this practice. For example, a farmer opened up an "illegal" plot on the riverside of the main canal in A block claiming that her family was unfairly deposed of its plot by an earlier white manager Mr. Young. "Illegal" gardens along canals now significantly increase water demand in Chakowa.

3.3 THE WATER DELIVERY SUB-SYSTEM

The weir

In 1935, Alvord sited the original abstraction some 200m upstream of the current weir. One individual farmer later sited a sediment free intake at the same location that got washed away by cyclone Eline. In the 1970s, Young built a half weir with an earth bank river training shown in photo 3.3.1.

It was founded on loose material comprising deep river deposits with stones and boulders. It was essentially a 10m concrete wall protruding upstream into the river at an angle of about 70 degrees to the river left bank. An earth bank of minimum two metres width at the top ran upstream for approximately 100m and effectively acted as a grassed earth divide between the main river and the diverted flow. The grass and reeds overgrowing the divide acted as natural reinforcement.

Silt normally clogged the weir intake entrance from upstream river activities. The other source of sand is the "gully" which comes in from the left and entered the river at the upstream end of the island. At its upstream end the grassed earth divide provided the separation between the canal diversion flow and the main river flow. There was no mechanism to divide or regulate flow into the canal diversion side of the earth bank or divide.

[2] Block A land was originally occupied by the Mutidzawanda family who were the traditional leaders: the current headman for Blocks A and B comes from this family.

The process of dividing the two flows is undertaken by farmers with the help of the local extension staff as shown in the cover photo.

Photo 3.3.1 Chakowa intake weir before cyclone Eline in 2000.

The canal network and storage dams

A lined supply canal links the weir to the first night storage dam (NSD_1) as shown in Fig. 3.3.1. The gate at the weir diversion is normally kept open to allow continuous flow into the irrigation blocks during the day and the night storage dams at night. A long weir type sand excluder, with a regulating sluice gate downstream and a flush-out sluice gate on the river side, provides a mechanism for flushing out sediment and diverting flow back to the river during canal maintenance. The operation of the flushing out is similar to the one at Deure. The maintenance foreman flushes out the weir alone. Immediately below the sand excluder is a DWD Parshall flume (L-2700mm, W-450mm). Unlike at Deure where the flume is at the field edge just before the first field offtake, at Chakowa the flume is at the river intake. There is no specific reason for the differential positioning of the devices. Operationally though the Chakowa flume requires the maintenance foreman to walk a long distance everyday to take readings. This may explain why at one time the taking of flume reading recordings had stopped[3].

The maintenance foreman also fights running battles with algae immediately downstream of the DWD main flume. He cleans the algae regularly using a hard broom otherwise it results in canal overflow. The algae problem is restricted to a 40 m section of the canal just after the flume. The fast flowing water from the hydraulic jump provides the aeration to blue-green algae that aggravates the problem. The very gentle slope of the canal at this point also facilitates the growth of the algae to levels that choke canals flow.

A parabolic channel conveys water between the flume and an inverted siphon. It passes through some fields and "illegal" gardens which abstract water from the canal. The inverted siphon inlet has a mesh to trap trash that the maintenance gang manually cleans about four times per day. If not cleaned the trash clogs off the mesh and flow is then lost via a lined

[3] On enquiring about the flume recordings everyone from all three extension workers, the clerk, foreman and builder denied any knowledge of such readings being undertaken by Agritex. Some even suggested that maybe the DWD "guy" who comes once a month probably takes the records. However, on bringing in forms for the readings to be taken I was shown a duplicate book supplied by DWD. The foreman clerk and EW acknowledged that the foreman used to take flume readings. The reason to stop taking and sending recordings was cited as lack of stamps since the government abolished the free postage service. However the recordings resumed and no one requested for stamps from me.

spillway provided. The farmers strongly condemn the inverted siphon because it occasionally clogs up and disrupts irrigation.

An open asbestos cement flume conveys water from the siphon to the first Night Storage Dam (NSD_1). This canal-Mutare to Masvingo road crossing has a drop and a wide channel that leads to settling of sediment. It is cleaned out regularly by the maintenance gang and is referred to as "the trough basin by the road"[4]. The canal off-take to block A NSD is just opposite the Agritex office and the gang ensures it is clean all the time.

The lined supply canal section between the two night storage dams is 5 km long. An unregulated gated bifurcation splits daytime flow between Block B and NSD for Block C and D. In the first the 3km section between NSD_1 and the bifurcation there are 45 “illegal irrigators” gardens of various sizes. Between the bifurcation and the NSD_2 there are 14 “illegal” abstractions. One garden has a mesh fence over the canal and trees planted along the canal making it difficult to follow the canal section. Another “illegal garden” is as big as 2 ha.

Some gardens have well built “off-takes'' from the canal. They have cement motor discharge points and understandably use siphons to draw water from the canal. The gardens all have hedges right round them probably meant to conceal the “illegal” farming activities and a water frontage on the canal.

Daytime and night-time distribution

The flow is split at a gated division with a short cross regulating weir structure into flow that goes into NSD_1, flow to a small portion of block A and the rest flows through a 2 km canal section to an unregulated bifurcation. Here daytime flows are divided to serve block B, which should irrigate with daytime flow only, and the rest flows to NSD_2 serving block C and D. Farmers in a small subzone of block A (see Fig. 3.3.1) divert water downstream of the NSD_1 intake. They therefore have the benefit of accessing daytime flow at any time at the head end. The only problem is that their soils are sandy like the lower blocks.

At night flow shared between NSD_1 and NSD_2. NSD_1 irrigates the upper and lower portion of the Block A on alternate days depending on the supply and demand fluctuations and problems related to water theft in the shared upstream distributary canal. Due to problems related to supply and demand fluctuations, (especially night flow theft mainly attributed to block A farmers and abstraction by “illegal gardens” along the canal section between the two night storage dams), blocks C and D irrigate from NSD_2 on alternate days or weeks. The causes of these inequities are discussed later.

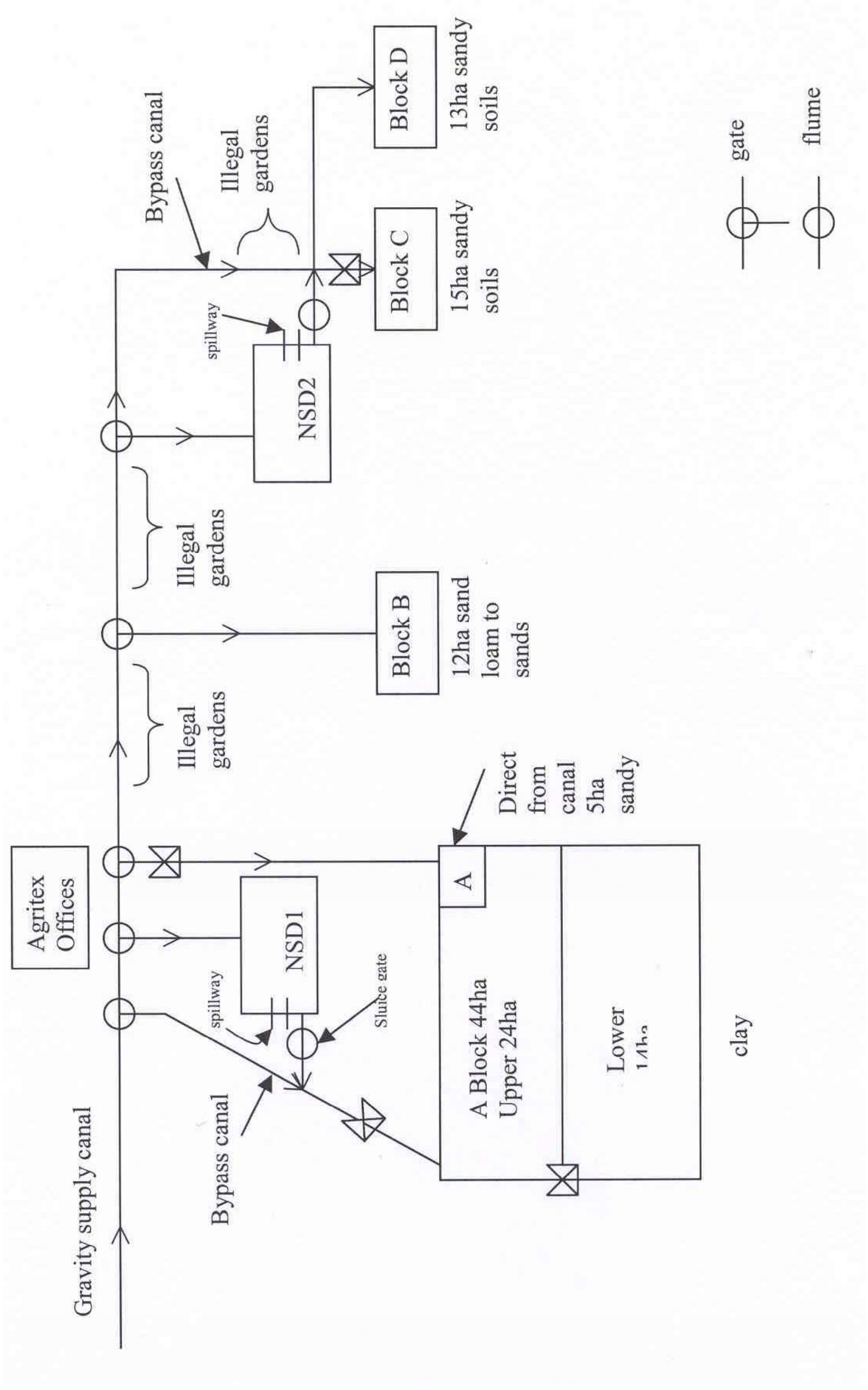
The distribution structures at Chakowa consist mainly of bifurcations or trifurcations with two or three gates downstream of the division box respectively. The water bailiff has to adjust all gates to get proper flow in the offtake canals. There are no defined rules and the bailiff learns from practice, often setting gates based on the number of holes in the gate frame.

There is an internal spillway that allows water to go into one downstream canal without overtopping if a gate is suddenly closed as shown in photo 3.3.2.
However, most gates leak most of the time, resulting in water trickling through the upstream canals even when not required. Once gates were locked, but there are no more locks found in Chakowa.

Farmers often assert their own possible solutions to problems. For example, on the problem of cleaning the inverted siphon, one farmer who is also a reputed local builder suggested that they should be allowed to sort out this inverted siphon problem. He graphically described how with his building experience he could facilitate the construction of pillars over

[4] The foreman says it is "to be cleaned yearly" in his work description book but in practice this box is cleaned more often. Whenever there is a break in flow the maintenance team gives priority to cleaning these road crossing troughs.

Fig. 3.3.1 Schematic Diagram of the Across-Block Distribution Network at Chakohwa



which a flume section could be built. No more water would be lost due to frequent siphon blockages.

Photo 3.3.2 Gated offtake with internal spillway at Chakowa

Sedimentation in the lined conveyance canal

Today there is evidence of sediment at canal bends which could be a technical or design issue but is also probably caused by lack of conservation works. Such works were initially unnecessary due to the low runoff in the natural vegetation area under low settlement density. Sediment from the catchment now gets into the canal from several causes, including: absence of drains; sheet erosion due to poor cover in the early summer season; and low velocity at canal bends. There were a few functional overchutes on the canal. A lot of sediment passed over these structures and over roads. The distribution canal road bridge just downstream of the first NSD just above plot 6a in the small block A gave a very good example of this. During the rains there was a lot of erosion just after the bridge and a lot of sediment was deposited into the canal upstream and downstream of the bridge resulting in its clogging. Some sediment was also settling in same the canal section due to the gentle gradient of the straight section canal after the drop. The canal section then overflowed and water ran down eroding the field road.

A second source of sediment is the early summer runoff that causes a significant amount of sheet erosion to take place in places that have very little grass cover. Land cover has been affected by increased land use attributed to cultivation, grazing, tree cutting, roads and other human activities in the zone through which the canal passes. This resulted in a lot of sand settling in the canal that had “a few overchutes”. The number of overchutes has not been revisited to cater for the increased settlement upstream of the canal since lining some 30 years ago. Leaves also need to be removed from the canals. They litter the area just before the rains, and are moved by wind and end up in the canal. Sediment and leaves regularly clog the inverted siphon, although this has no regular timetable for cleaning like its mesh cover trap.

The section after the bridge had a bend and the canal water velocity decreased leading to deposition and overflow of water from this section too. This phenomenon was evident at most canal bends. The overflowing was most noticeable on Saturday and Sunday afternoons. Most of the farmers especially those on the head-end of Block A go to church on Sunday after 1000 am. It is possible to prevent such overflowing and sedimentation by re-designing. Canal bends need to be designed with a radius of curvature that varies with the discharge and ensures that canal flow maintains a minimum velocity that prevents settling out sediment as given in the design of small canals handbook (Aisenbrey *et al* 1978). This principle was applied in some rehabilitation and new scheme canal designs, as at Deure.

Understanding differences between blocks

When the scheme was initiated in 1935 the head-end block A was developed first. This block has clayey soils and has for the most part gentle slopes that are better suited to surface irrigation than other blocks as shown in table 3.3.1.

Table 3.3.1 Chakowa irrigation scheme: general data

Block	**A**	**B**	**C**	**D**	**Total**
Area (ha)	48.5	12.7	15.3	13.2	89.6
No. of plots	60	17	29	23	129
Avg. plot size	0.81	0.75	0.53	0.57	0.67
Soil type	Sandy clay	Sand loam and sand	Sand	Sand	
Summer Crops	Maize, okra, Groundnuts and tomatoes	Groundnuts, Maize and Tomatoes	Groundnuts and Maize	Groundnuts and Maize	
Winter crops	Beans, tomatoes, onion and wheat	Beans	Beans	Beans	
Irrigators / day	9 +3	2	3	3	20
Irrigation frequency	7 and 14	7	8 to 14	8 to 14	
Source: field observation					

The soils in the four blocks are different, ranging from sandy clays in a greater portion of block A to medium grained sands in most of block C and D (Senzanje et al 2001). Farmers in Block C and D claim they have to put in a lot of fertiliser to achieve an appreciable yield and yet their counterparts in block A put in less. They say that the colonial government recognised these differences in fertility and as a result their blocks paid less fees than the Block A irrigators. *“Tino wana zvishoma, kana uchitoda kukwikwidzana neve kunamba wani unoto shinga pafetiraiza, saka mutero wedu unofanirwa kuita mushoma”*(We get little, if one wants to compete with people from block A, one has to commit himself to buying a lot of fertiliser, that is why we should pay less rent). A few people who occupy a sandy portion of block A seconded this grievance. However this group was not so bitter about it as they have a reliable and frequent supply of water. They abstract directly from the continuous flow supply canal. Block C and D have lower frequencies due to water theft from the canal by mainly illegal irrigators and unscheduled upstream irrigators during the day, and canal diversion during the night as discussed in section 3.6.

The varying plot holding sizes reflect the rationalisation of plot size already discussed. The differences in crop choice shown in table 3.3.1 are due to differences in water availability between blocks in the system. It is interesting to note the difference between what representatives (Agritex EW and IMC Chairman) first cited as the cause of this inequity, and what later emerged in the research especially after cyclone Eline.

At first the differences in practices were presented to the researcher as resulting from soil differences only. The Chakowa farmers’ view is that sandy soils require a lot of water because of its high infiltration. This resulted in the tail-end blocks C and D resorting to planting only when the rains have wetted the ground to reduce their irrigation water requirement. This provides a situation where the scheme is fully cropped in summer as supplementary irrigation and the intensity in winter is governed by the farmers’ view of water availability. They did not mention or attribute inequality to management or social issues at first. They simply explained that block A required less water because of their heavy soils so the farmers could afford to plant early.

Finally, it was alleged that the people from block A got most of the water by hook and crook. The people in block D were the most bitter about these inequities in water distribution. *"Vanhu vheku namba wani ndivo vanoto wana mvura yose. Amweni anoto uya ngeusiku, vachi dirira nemvura inofanirwa kuenda kudamu reku namba three".* (The people in block A are the ones who get all the water. Some of them irrigate at night poaching water that is intended for the night storage in block C). Some farmers from block A at the tail end also complained of inequity in water distribution within the block. This is discussed further in section 3.6.

Water at plot level

Alvord planned and designed the field distribution at Chakowa. He surveyed and supervised the pegging of the canals. Initially most of the canals were designed with the maximum possible length in all blocks. Farmers initially performed all field levelling of their plots at Chakowa as was also reported at Mutambara, Deure and Nyamaropa (Manzungu et al 1996, Magadlela 2000). In choosing field designs Alvord was largely guided by his desire to mobilize, convey, distribute and apply water by gravity to inherently fertile lands in block A at Chakowa so as achieve sustainable development. However it is understood that he was later involved in the planning of the extension to less fertile soil probably as a response to increasing pressure for irrigation lands once the locals started to appreciate its benefits.

The long unlined canals persisted at Chakowa and most other schemes until the 1970s when a policy of lining canals and reducing lengths of borders to manageable lengths was adopted for most schemes. Lining of canals was accompanied by shortening the length of run and construction of night storage dams at Chakowa as the focus shifted to better water management in order to cater for the increased irrigated lands. This was in line with the policy of increased government control in irrigated lands that caused misunderstandings at schemes like Mutambara as discussed by Manzungu (1996, 1999).

Use of lined canals heralded the start of use of siphons as water application gadgets that could theoretically increase water application control. Most of the siphons used in Zimbabwe are three metre lengths of rubber or rigid polyvinyl chloride (PVC) pipes. These pipes vary in diameter from 40mm to 50 mm mainly. Rubber pipes obtained from mining areas are gaining popularity at schemes like Chakowa because they are reputed to last longer. Rubber and PVC siphons can be primed by the up and down movement or by simply submerging the pipe and pulling it out with one end tight closed. The rigid PVC siphon ends quickly wear away if farmers prime using the up and down palm suction creation method[5].

The replacement of siphons used to be a responsibility of government in old schemes, and at most schemes including Chakowa, only a single set of siphons were used (Manzungu 1999, pp104). Generally the Chakowa farmers use 8 to 10 siphons per farmer and each farmer irrigates one border per time as shown in photo 3.3.3.

This is the practice at most schemes in Zimbabwe. Farmers estimate the life of an average PVC siphon at one to four seasons depending on the user's care. Generally there is erosion at the siphon discharge point even at the nominal siphon design head of 15 to 30 cm. In most schemes as observed at Chakowa and Deure the farmers use maize, wheat and groundnut stover or plastic bags or sheets to reduce erosion.

[5] They move the pipe up and down with the palm opening the pipe free end to release air during the process of pushing the other siphon end into the water. The palm then closes the open end as the water filled siphon pipe is pulled up. During these movements the siphon will rub against the bed and sides of the canal, leading to wear and eventually openings or holes. Some farmers tie the holes with rubber to extend the service life of the siphon pipe.

Photo 3.3.3 Use of different siphons at Chakowa

Individual farmers now buy and use their own siphons at Chakowa. Farmers view the replacement of siphons as a major cost item resulting in a number of them shifting from using black plastic PVC to rubber hoses. There is a dealer at the scheme who supplies the mining rubber hose. The life for rubber siphons is not yet established at Chakowa since the product is relatively new although they are widely believed to last longer than PVC. A number of farmers currently use a mixture of different material and different diameters of siphon pipes. This is accompanied by the use of different numbers of siphons. The farmers do not have proper check structures. They use various combinations of stones, soil and plastic sheets. A typical check is shown in photo 3.3.4.

Photo 3.3.4 A typical stone and plastic check at Chakowa

Beyond cropping in formally allocated plots, the poor water control allows illegal crop production in a number of locations. Bananas have been left to grow along the main canal of block A, resulting in their roots undermining a significant proportion of the lined canal as shown in photo 3.3.5.

As mentioned earlier there is leakage through gates controlling the night storage reservoirs, and drains are not maintained. Thriving crops of sugar cane may now be found in old drains and water seepage areas, even while downstream blocks wait desperately for water.

Photo 3.3.5 Bananas undermining lined canal in block A Chakowa

Canals in Block A often overtop and the clayey soil gets wet and consolidates under the weight of the canal, leading to sinking of sections of the canal, mainly on the irrigation field side. Farmers with the help of the Agritex builder have then added a layer of bricks to retain the original side level and avoid further overtopping. To reinforce the canal after the banks are eroded away completely the farmer imported stones. Some canals leak visibly due to the eroded embankment, and a portion in the upper section of this block has a field that is waterlogged due to canal leakage. Being both a field irrigating canal and a canal supplying water to fields about 3 km downstream, the canal is continuously full. The drainage in this upstream section is not well maintained, with sugar cane and bananas flourishing.

3.4 THE EVOLUTION OF THE MANAGEMENT SUPPORT SUB-SYSTEM

Management between 1970 and 1980

Farmers could recall the old management system, before independence, especially after the arrival of Mr. Young around 1970. This white manager moved from Nyanyadzi to take residence at Chakowa after the addition of the other blocks. He supervised lining of the main canal and the construction of the two night storage dams. Additional canals especially in Block A were constructed, resulting in the shortening of some of the borders to their present lengths of 100 to 120 m in the clay soils and about 60 to 70 m in the sandy soils. Most of the distribution canals were also lined. At Chakowa as in most other schemes land levelling from this time on was done using earth moving equipment. In Zimbabwe dozers and motorised graders have traditionally been used to carry out rough and final levelling of fields. Farmers are responsible for constructing borders and furrows. Borders are expected to have nil or minimum cross slope, and are generally between 2 to 3 m in width at schemes like Chakowa. The expansion of the scheme to embrace block B, C, D and E is understood to have taken place at an earlier date. Young rationalised the scheme to its present size by cutting off block E around 1970. A 15 men team was responsible for maintenance and operation. They had a complement of equipment that included tractors, tow grader and other levelling and building accessories[6].

[6] According to the Chakowa maintenance foreman most of this equipment was later taken to Nyanyadzi and was never returned.

The manager took an active interest in water distribution and application. Farmers in all blocks shared a set of siphons provided by government. The siphons were kept in siphon houses that were close to the night storage dams for block A, C and D[7]. Since his residence was opposite the first night storage dam and the siphon house for Block A, the manager ensured that the plotholders for this prime and biggest block A at the head-end practised fair irrigation. Farmers claim that water was shared equitably under his management. Each farmer in all blocks is said to have got water within a period of a week to a maximum of 10 days. Perhaps his strategic control of the block A irrigation operations really provided the basis for his success in management of water distribution. He is also reported to have used the unpopular approaches of production monitoring and exclusion for ensuring good irrigation practices.

Generally farmers at Chakowa feel that water delivery under this strict control practice was better than the current situation. Magadlela (1999) documented similar sentiments at Nyamaropa. However farmers were not happy with the enforced cropping practices that forced them to irrigate crops like cotton. Farmers had to adhere to recommended cropping programs. Centrally marketed crops like maize, wheat, and cotton were grown. Farmers got credit and paid for inputs through deductions. This provision of inputs ensured that farmers adequately provided fertiliser to crops. The old structures used for administration of this practice are evident at Chakowa e.g. depots and storerooms. A poor crop stand under these conditions of good water delivery and good input supply could only be interpreted as a sign of incompetence. The crop viability issue was taken out of farmer’s decision or control capacity. The best way out with poor productivity (which was the basic performance measure) then was to warn the farmer a number of times, monitor progress and if nothing changes alleviate the situation by plot rationalisation. Plot rationalisation meant cutting a plot to a suitable size for the farmer to try again. The other portion was given to those on the waiting list. Each scheme manager kept a very active waiting list. Some new entrants always found themselves allocated pieces extracted from poor performers[8]. Performance was then measured by good stands on recommended crops with recommended water delivery.

A maintenance gang that was based at Nyanyadzi used to be responsible for weirs and other structures at Chakowa. A typical maintenance gang was around 60 men for a 400ha scheme operated under the irrigation manager (Magadlela 1999). The last manager at Nyanyadzi had a 10 permanent member gang stationed at Chakowa (personal communication with Chakowa foreman)[9]. These would do routine jobs as summarised in table 3.4.1. During periods of peak maintenance requirements at either Chakowa or Nyanyadzi the manager would group the team and direct them to specific action sites. The team had a fleet of tractors, lorries, dam scoops, and light vehicles to support them. A small dozer was also allocated to

[7] Siphon houses are still evident at many old schemes like Tawona, Deure and Nyanyadzi. Farmers at some schemes like Tawona still share siphons although storage is no longer in the siphon houses. Those who share siphons normally do not practice night irrigation (see also footnote 17). Farmers at Musikavanhu still share siphons but they do not have siphon houses. Farmers in most schemes including those at Chakowa and Deure now own individual siphons and invariably take them home after use.

[8] The plots were never consolidated and they are still found in different locations of the scheme although they now belong to one farmer.

[9] The Nyanyadzi manager retired at the time the irrigation manager post was abolished. He went back to his Mutema home where he is a sub-Chief. There will be more encounters with him there in chapter 5 as the local community used him to bargain with the government authorities especially on operation and repair of the Mutema irrigation system.

the Nyanyadzi-Chakowa scheme team when it was transferred from Derude[10]. Most of the equipment is however not working because of lack of service and obsolescence.

The financial allocation for maintenance was split into a regular provision that covered recurrent items and works like uniforms, road grading, purchasing shovels and other routine maintenance equipment. This was allocated based on bids placed by each scheme and therefore varied basically with the scheme size, nature of artefacts and age of system. Head office and the provincial specialists managed the provisions for unanticipated damage due to floods and breaches. Provincial specialists through their respective Chief extension officers indented into these funds. With the reduction in general allocation and rise in pumped schemes this maintenance allocation component suffered the most. The irrigators and local extension staff were aware of this situation. Therefore they had devised mechanisms for dealing with minor emergency maintenance needs as illustrated by problems due to the 1999 and 2000 floods.

The Agritex Maintenance Crew

Before 1980 there was a fifteen -member maintenance gang but this was reduced to five (5) by 1999. It further shrank to four (4) when the builder retired in year 2000. Those who have retired or died have not been replaced as government has seen this as a way to cut down on its expenditure. The maintenance foreman and another elderly man are fully responsible for maintenance. The other two middle-aged men have been appointed water bailiffs and only join the maintenance crew when there is no irrigation (which rarely happens). No one exactly supervises the maintenance crew, although one of them is the foreman. Their main functions identified in the maintenance foreman work-plan for year 2000 are highlighted in table 3.4.1.

Maintenance of infrastructure at Chakowa is now a shared responsibility between the farmers and Agritex, both institutions chip in as summarised in table 3.4.1. Certain rules are said to exist which govern maintenance within the scheme but were never given to me in black and white. Rules that existed originally were sidelined after independence, as they were associated with oppression.

Each farmer is supposed to maintain his/her section of the field canal. If a section of the canal breaks - for example during ploughing - the farmer is required to buy the materials necessary to repair that section. These are given to the maintenance crew who do the repair of the broken canal section. Some farmers however were complaining that some of their fellows were not buying the material to repair their canal sections, and this was reducing the water conveyed in their field canals. It was not clarified who was responsible for monitoring the farmers, but both Agritex and the IMC were involved.

Extension workers have taken over most functions that were previously performed by the irrigation manager at Chakowa. They are responsible for supporting the water distribution issues. There has been very little management support coming to Chakowa from Nyanyadzi over the years. The rationalisation in Agritex saw the authority of even supervisors decreasing to a level where they were in the same category with officers and extension workers. The supervisor's post was stripped of its management functions in the early 1990s. The team approach probably severed this last link. The EWs at Chakowa were no longer in the same team as Nyanyadzi in late year 2000. Water bailiffs and maintenance team reported to the

[10] Ironically irrigation maintenance equipment was moved from Derude to Agritex in the late 1980s. The "same equipment" was recently moved to the DWD where a new Department of Irrigation and Water Development was being formed that later became the Department of Irrigation in the same Ministry of Rural Resources and Water Development.

Table 3.4.1 Summary of maintenance practices for the Chakowa conveyance canal

Activities	Seasonality	Critical Period	Time Taken	Peak Frequency	Man Power Needed	Contribution		Equipment Used	Remarks
						Agritex	Farmer		
Sand excluder flushing	Year round	Nov-March	15 min.	Daily	1	**1-foreman**	Nil		Farmers not involved. Foreman walks 4km.
Reading flume	Year round		10 min.	Daily	1	1-forema1n	Nil		
Removing blue-green algae	Year round	Aug-May	1 hr.	Every third day	1	1-foreman	Nil	Hard-broom	
Cleaning inverted siphon entrance*	Year round	Aug-Dec	15 min.	Every 4 hours	1	1-foreman	Occasional	Stick	Framers want redesign due to flow reduction
Desilting conveyance canal & road crossings*	Year round	Nov-Jan	2-days	Every week	3	2-including foreman	Nil	Shovels	Understaffed focus on road crossings
Cutting grass along conv.canal & NSDs*	Nov-April	Dec-March	1-week	Every month	4	2-including foreman	Nil	Slasher	Neglected, Farmers not interested
Conv. Canal Overchutes cleaning*	Nov-April	Nov-Feb	1 wk	Every month	4	2-including foreman	Nil	Shovels	Neglected, Farmers not interested
Conv. Canal service road mantenance	Nov-April	Nov-March	1-wk	Every second month	4	Nil	Nil	Nil	Total Neglect, now footpath
Conv. Canal fence maintenance*	Year round	Year round	1-wk	Every month	4	Nil	Nil	Nil	No more fence

Source: field observation* identified in foreman's workplan

EWs[11]. The EWs at Chakowa were all ordinary extension agents of the same rank. A female EW was responsible for the Chakowa scheme only, before the team approach.

The maintenance foreman keeps an elaborate record of the maintenance activities they do everyday. He is always keen to make it available for inspection. His major complaint was that they are now so few that they can no longer do all the work they used to do. They have tended to focus attention on the main canal that requires constant attention as it has a direct effect on water delivery performance. They do very little work in the local distribution and drainage system.

On taking over maintenance the EWs have focused on water delivery tasks. Issued that like snail ranging have tended to receive little or no attention. At Chakowa there are many snails observed especially near the NSDs where continuous wet conditions provide favourable growth conditions for this bilharzia vector. The foreman complained that there is always danger of catching bilharzia especially now that programs of molusciding are forgotten. He however gets frequent tablets from the neighbouring clinic.

Irrigation Management Committee

An Irrigation Management Committee, first initiated around 1981 just after independence, assists the EWs in water distribution. Members of the block committees (BIMC) form the main committee (CIMC). In theory the EWs, BIMC and CIMC should provide the water bailiff with all the support required in ensuring good water distribution. They hold meetings and pass resolutions on how to ensure that water is properly distributed. Their involvement is discussed further in section 3.6. In 1998 the chairman was a soft-spoken elderly gentleman who was renowned for hard work[12]. During the study period a new committee headed by a young male farmer in block A was voted in replacing the old committee. However most of the old committee office bearers were elected to posts of deputies (vice) to the new office bearers. An example is that the former chairman was elected to the post of vice-chairman and the former secretary became the vice-secretary and so on. They explained that this was meant to input new blood by electing new young and active office bearers. They also ensured continuity and stability by retaining the old committee as deputies to the younger incumbents.

The Chakowa IMC is an institution formed locally with support from the local Agritex officials. The two local headmen are co-opted as ex-officio members. They are expected to play a role in advising the IMC as necessary, but they have no structural powers or specific responsibility that they exercise as community leaders. The local councillor elected under the local government structures had no specific role or relationship with the Chakowa IMC. There was therefore no opportunity for the initiatives coming from the councillor to be fed directly into the IMC. The IMC also did not have direct interaction and input into the councillor's activities and agenda. The IMC at Chakowa therefore remained obscure to the local government structures. This situation was different in Deure as discussed in chapter 4.

Maintenance fees are rarely paid. In 1999 the clerk from Nyanyadzi, the administrative centre for the two schemes, spent one day waiting for payment after farmers had sold off beans at a minimum of 500Z$ per 25kg: under contract Monaken had paid out for 37 tonnes alone from Chakowa. However, the lady clerk recorded only one payment from one irrigator who was thus the only 'paid up' irrigator at Chakowa in 2000 – this was the maintenance foreman.

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[11] This arrangement has been further complicated by the transfer in 2002 of O&M staff to MRRWD and the extension staff to the new department of AREX in the MLARR.

[12] He runs a fleet of lorries and most of the occasions he would come in one of his lorries putting on overalls. He commanded a lot of respect. His plot was in block D and his homestead is about 3km from the scheme in the Chaseyama area.

Access and marketing

Internal roads are poorly maintained, and the distribution canal between the two NSDs is hardly accessible. Parts of the canal section are fenced in "illegal gardens", and grass is not cut back by maintenance staff due to lack of resources and labour. The road network for maintenance and inspection of the field canal is not cared for. There is frequently tall grass growing in the roads and along the sides of the canal in the areas not lined. Some upstream farmers only cut the grass to avoid harbouring mice that feed on their beans. They sometimes burn the grass when the bean pods start forming. No one worries about the need to cut grass or repair roads during summer. Getting about the field is therefore always a foot expedition[13]. There are no more roads for cars to go round to most plots in block A.

Marketing is done through the transport resources of farmers (such as the lorries of the previous IMC chairman) and the outside vendors who have rented plots. The scheme farmers especially women form the core of the market operators. A few outside vendors have settled in and make a living by marketing and renting plots to grow maize for family needs and beans for the bean market[14]. Produce that cannot be entirely marketed on the Chakowa roadside market is taken to Mutare. Local women are the dominant traders: as discussed later in section 3.6 most of these are the tail-end farmers who buy from the head-enders. Okra, early groundnuts and early tomato are the main products. A number of farmers working in Mutare commute in personal vehicles and are thus important players in providing market intelligence to the scheme. These two markets significantly enhance the income obtained from irrigation farming at Chakowa and give rise to the "job" status that farmers give to the enterprise. The importance of the vegetable market to Chakowa is also the source of the current chronic head-end tail end problems in water delivery that this chapter will demonstrate. To secure reliable water for their high-income crops the head-enders have mobilised all the scarce water available and appropriated it on a permanent basis.

3.5 IRRIGATION PERFORMANCE IN THE SCHEME

Hydraulic performance

The water delivery to Chakowa as measured at the intake weir is characterised by a high water supply to the whole scheme as given in figure 3.5.1 with very high abstraction almost constant throughout the year. The flume intake readings are recorded continuously and indicate the amount of water diverted to the scheme irrespective of its actual use for irrigation. The net result is that during periods of crop change over and low actual use of water at the scheme the calculated RIS is high. During the late summer periods there is virtually no use of the diverted flow. There are no seasonal storage or regulation structures to store this excess or uncommitted flow. Crop changeover from winter to summer in September also leads to high RIS as the diverted flow is not utilised by farmers. There was a lot of flow that simply passed through the canal without being utilised by farmers. The in-block flume readings show lower peaks than the whole scheme flows, as farmers tended to utilise any flow diverted off the main canal even if this leads to waterlogging or irrigating bananas in drains.

[13] In fact the maintenance foreman and the water bailiffs insist that one needs a stick to scare away snakes as they walk through the tall grass. Occasionally one jumps to the surprise of dogs guarding the fields against baboons.

[14] While Chakowa produces beans its size makes it a relatively small player on the bean market. The market is controlled by larger schemes who bargain with the clique of buyers on an annual basis to determine market prices. Schemes like Chakowa only provide price skimmers who enter the market early.

Demand in winter periods brings down the whole scheme relative irrigation supply (RIS) to a minimum of about 4 in winter and about 3.3 in early January as shown in figure 3.5.1. Makadho found a whole scheme relative water supply (RWS) for Chakowa of 4.18 in winter 1990 (RWS=RIS in winter in Zimbabwe). It was the highest in the sample of schemes considered followed by Mutambara with 2.87 and Nyamaropa with 2.67 (Makadho in Rukuni et al 1994, pp59). The whole scheme RIS is much higher than that for the individual blocks[15]. This is attributed to the large amounts of water that the scheme continuously diverts from the river to serve very low cropping intensities, except in the normal summer and winter periods of November to January and June to August respectively, that are only restricted to the head-end block A where farmers grow early crops like okra and groundnuts. A lot of water in quantitative terms is being used for the frequent but limited okra watering regimes and therefore simply running through the scheme during these periods.

The water used in individual blocks was measured during actual irrigation periods only and also took account of unused flow, thus substantially reducing the water account for the blocks relative to the whole scheme duty. The hydrological records at Old Cashel Bridge however shows that rainfall in 1998/99 was above average and therefore these results of water delivery performance can only be considered as one case of practice at Chakowa. Inequity, following illegal practices and the effects caused by the hydraulic limitations across blocks, is evident for this above average rainfall category. However the practices in situations for below average rains, when even the head-end farmers have to apportion limited flows among themselves, cannot be ascertained from this study.

Inter-block equity and adequacy

While I had noticed that the lower blocks - particularly D block and to some extent C block - planted crops late, the farmers interviewed attributed this to sandy soils, which required a lot of water. They therefore waited for the main rains to start up good summer crops. When I suggested that in theory they could be tail enders being denied water, they either denied that or simply kept quiet, perhaps because I was a stranger. The consistent involvement of the chairman from these lower blocks in all scheme activities, and especially at the weir, gave the impression that everything was fine.

Figure 3.5.1 shows that water diverted to the head-end block A gives a winter minimum RIS of about 2 that occurs in July and a lower early summer RIS of about 1.5 occurring in January. This reflects the ease with which Block A farmers can take (or steal) water. These low RIS figures reflect periods of maximum demand. In winter most of the area will be under beans in all blocks.

The small Block A section receives direct flow during the day only and has sandy soils, unlike the head end block which is irrigated from the night storage dam and has heavy soils. The small Block A is mainly put under early groundnuts, unlike the head-end Block A that is planted to okra. The RIS of the small Block A is intermediate between that of the head-end block A and the tail-end block B as shown in figure 3.5.1. The cropping program of block B resembles that of the other tail-end blocks C and D. Block B generally has a RIS below 1 during peak demand periods in both winter and summer indicating inadequate water supply. The RIS of the head-end block A never fell below 1 during the study period indicating that supply always exceeded demand.

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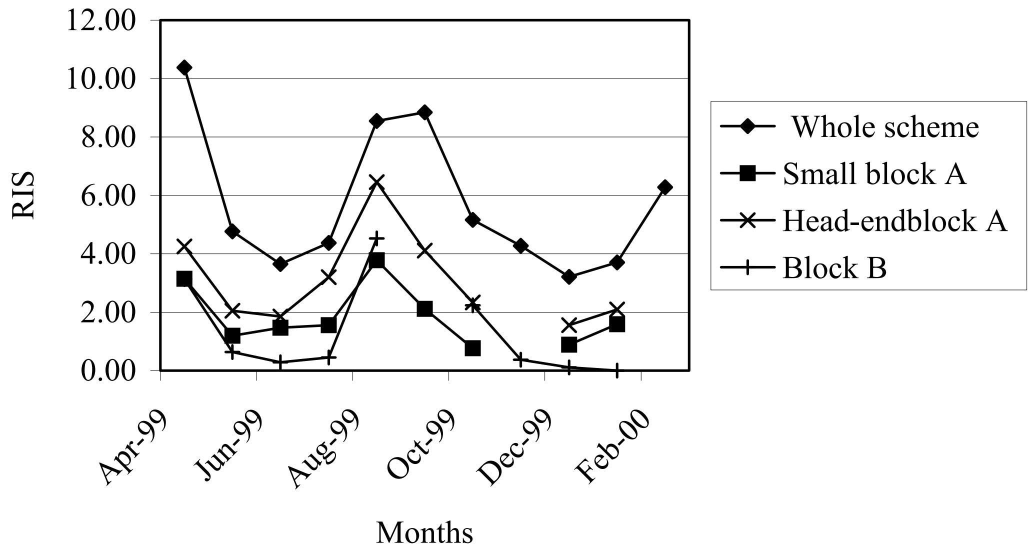
[15] The RIS for the whole scheme was obtained from dividing continuous supply measured at the scheme measuring device, the flume just after the intake near the weir, by the crop water requirement for the whole scheme based on the cropping programme for the whole scheme. The block-level RIS were obtained from flume measurements made at the entrance and exit of the specific blocks during the study and dividing by the crop water requirements. Crop water requirements were as determined by the Penman-Monteith method.

Figure 3.5.1 Chakowa RIS Comparisons



The January peak demand is due to the high cropping intensity, as the tail end blocks B, C and D will have completed planting as shown in table 3.5.2. The high RIS in the period April to May occurs due to the low irrigation demand as most farmers are still planting beans - the main winter crop. The lower blocks also tend to start later in April while the head-end block generally establishes an earlier bean crop. This could be attributed to the head-enders in block A monopolising the flow. They also have less field activities at this time as they would have harvested their summer crop much earlier than the late-planted tail-end crop.

The high RIS in September is due to the continued diversion of water to irrigate only the head end block A and its early crops of maize, groundnuts and okra. The lower blocks have learnt from experience not to venture into these crops. Even though these farmers have adjusted their cropping to supplementary irrigation, the water diverted into the system is still fairly high relative to the cropped area and this leads to the high values of RIS. The indicator RIS tends to display volatility when there is a low irrigation requirement. This situation suggests that the Chakowa scheme could benefit greatly from stabilisation of the water supply to both capture and effectively utilise the flow wasted as excess delivery throughout the year. This will also even out delivery over the year and seasons, and possibly lead to more security, confidence and farmer co-operation as highlighted in Deure in Chapter 4. This is in line with the MP's desire as discussed in section 3.2. The excess flow diverted and not utilised by the scheme, in the slack period from September to October, requires that delivery be stabilised - as well as management and social interventions to be fully mobilised.

Field application practices and performance

The land levelling problems at Chakowa that were created 30 years ago have still not been attended to. The mobilisation of re-levelling is not an easy activity and very few developers want to entertain it. In practice the farmers end up coping as discussed earlier. They manage to substantially raise the distribution uniformity with time. There are very few fields where farmers irrigate without ties and having to train the water. On the few that one witnesses, farmers proudly say that they are sitting well "*Wakagadzikana zvakanaka*". I witnessed a few in block B11 at Deure, and Mada reports the same for plot A2-147 in Musikavanhu Block A2 (Mada 2000). The Chakowa water bailiffs strongly believe that being able to satisfactorily level a field is a sign of a good farmer. Field Application Uniformity parameters were measured at Chakowa and performance indicators are summarised in table 3.5.1[16].

Table 3.5.1: Summary of Performance Indicators for Chakowa Scheme

Block	A1	A2	B	C	Average
Ea (%)	10.73	17.77	36.08	34.26	23.6
Er (%)	69.92	100	90.4	88.8	85.2
DPR(%)	89.2	82.63	63.1	65	76
TWR (%)	0.24	0.6	0.83	1.07	0.6
CU (%)	85.46	80.42	83.35	82.14	83.2
DU (%)	75.9	68.8	82.93	69.9	75.2
Ec (%)	87	87	87	87	87
Source: Senzanje et al 2000					

Application Efficiencies (Ea)

The application efficiencies are generally low with an average of 23.6 %. This figure is lower for the head end block A than the tail end blocks. In both cases there is room for improvement judging by efficiencies that are possible from international literature.

Requirement Effiencies (Er)

The figures show that the scheme farmers generally get all the water they require when they set out to irrigate. The lower end farmers of this block who plant and never manage to mobilise water from the head-end farmers probably contributed the low requirement for A1 of 70%. The high figures recorded for the tail-end blocks C and D are due to the farmers' practice of not planting until they are sure of water availability.

Deep Percolation Ratio (DPR)

The deep percolation ratio of the head-end blocks is fairly high and illustrates the excess usage of water by these farmers. This has been highlighted in the serious head-end tail-end conflict at Chakowa. The ratio is much less for the tail end blocks C and D. A stream size of 6.5 to 10.3 l s^{-1} m^{-1} was obtained using 9 to 10 siphons per 2 to 3m width border that is 2 to 5 l s^{-1} m^{-1}. This is considered small for medium sands of the tail-end blocks C and D and fair for the sandy clays of the head-end block A (recommended 10-15 l s^{-1} m^{-1} for sands and 3-6 l s^{-1} m^{-1} for clay (Kay 1986). The head-end farmers apply too much water because they applied it for longer, rather than due to a technical problem of water control (Senzanje *et al* 2000). The high deep percolation ratios account for the high frequent fertilisation practices that okra farmers have adopted. The practical technical inability of surface systems to apply and control small depths of water for light soil cannot be ignored here (Cornish 1998, pp3).

Tail water Ratio (TWR)

Chakowa like many other schemes practices closing of borders to prevent runoff and this explains the low figure. In other schemes like Nyamaropa farmers are fined for losing water through runoff (Magadlela 1999). The magnitude of this indicator therefore reflects most farmers practice due to their set objectives and perception, rather than good surface irrigation water control.

[16] Student Ian Samakande did the field application measurements under this study program as part of the BSc Agric. Eng. Degree project course work. This involved monitoring water application practices including advance and recession on a number of bunds in each block. Infiltration tests were carried out and bund slopes determined. Soil samples were taken and soil moisture levels determined. The data was then used to compute field application indicators summarised in table 3.5.1.

Christiansen's Coefficient of Uniformity (CU) and distribution uniformity (DU)

The uniformity figures for all blocks are high. This is mainly due to the general practice of making ties (cross-dykes) to control flow: various practices in different blocks are shown in figure 3.5.2. The major question for Chakowa is whether it is possible to apply low irrigation depth and still achieve high uniformity especially for the head-end blocks. **The leverage seems to be stream size management for both head-end and tail-end farmers**. There is need to increase the stream and improve its movement down the bund. Such practices are easier to adopt when the delivery is secure and reliable. High application depths have been used as buffer storage in insecure and unreliable delivery situations.

The problem of inequitable water distribution has grown to a very high level at Chakowa, and yet any outsider who just graces the scheme for a short time may never notice. The bigger block A is just below the Agritex offices and under normal conditions the crops as observed from these offices look good. The activities of marketing and reselling crops are conducted at the Chakowa business centre that is close to this block. Farmers in the downstream blocks are generally residing further away. The seriousness of the inequity is reflected in the difference in planting patterns. Block A farmers grow a variety of early crops, while downstream block D farmers are restricted to late maize and beans as shown in table 3.5.2 and 3.5.3.

The irrigation in block A is characterised by early planting in summer. Farmers plant their first okra *(derere)*, tomato and groundnut crops as early as mid July as shown in table 3.5.3. Last plantings of this crop are in December meaning that the block has a continuous water use programme from beans to these intermediate crops then maize. Block A maize is planted as early as mid July with last plantings at the end of October. There is hardly any maize planted in November or December when B, C and D are planting their main crop as shown in table 3.5.2. This suggests that the period of low flow that occurs in July to November is generally utilised by block A which is at the head-end[17]. All blocks utilise the high base flow from March to July for the bean crop that is grown by the whole scheme. Most farmers plant in April and May. A few farmers in head-end block A plant beans in March and the last bean crop in the tail–end block D is planted in July as shown in table 3.5.3. Wheat is a minor crop on all blocks although few farmers grow it with a bigger number in block A.

The bigger area and bigger crop variety tends to increase the water demand and use of this head-end block A compared to the others. Generally farmers in this block can spend up to 3 consecutive days irrigating their plots. With the size of this block there is also a fair amount of in-block distribution problems that have been noted. These problems are not as pronounced in the other smaller blocks.

The period of November and December were observed to be the most demanding in terms of water at Chakowa. For Chakowa two factors combine to increase the severity of the demand, that is the high irrigation requirements and sensitive water need for mainly maize and the low river flow in most years. Table 3.5.2 shows that most of the crop for block B, C and D is planted in the period October to November. This leads to high irrigation water requirements (IWR) in November – December or low RIS as shown in figure 3.5.1. The block A early crop will also be requiring water.

[17] Ironically, if the old priority water right system was applied internally to an irrigation system, block A farmers could have legally denied water to other blocks, as block A was developed first with 'prior right to irrigate in water scarcity situations.

Table 3.5.2: Crop Planting Date and Area Planted (bunds), Early Summer 1998

Block	**Month**	**Jul**	**Au**	**Au**	**Se**	**Se**	**Oc**	**Oc**	**No**	**No**	**De**	**De**	**Total**
	Date	**16-31**	**1-15**	**16-30**	**1-15**	**16-31**	**1-15**	**16-30**	**1-15**	**16-31**	**1-15**	**16-31**	
	Crop												
A	Maize	31	37	44	12	25	185	139					473
	G-nuts	26	27	74	7	13	12						159
	Okra	22	20	20	0	2	10	2	2				78
	Onion		1	1									2
	Tomato		4	0	0	0	3	0	0	0	9		16
B	Maize					37	23	128	118	47			353
	G-nuts		4	0	0	20	30						54
	Okra												
	Onion					9	6						15
	Tomato						8						8
C	Maize					39	68	82	138	145			472
	G-nuts					19							19
	Okra					2							2
	Onion					44	12	0	0	0	12		68
	Tomato					7	11						18
D	Maize						52	0	289	245	21	60	667
	G-nuts					43	7						50
	Onion					13							13
	Tomato					15							15
Source: Field observation													

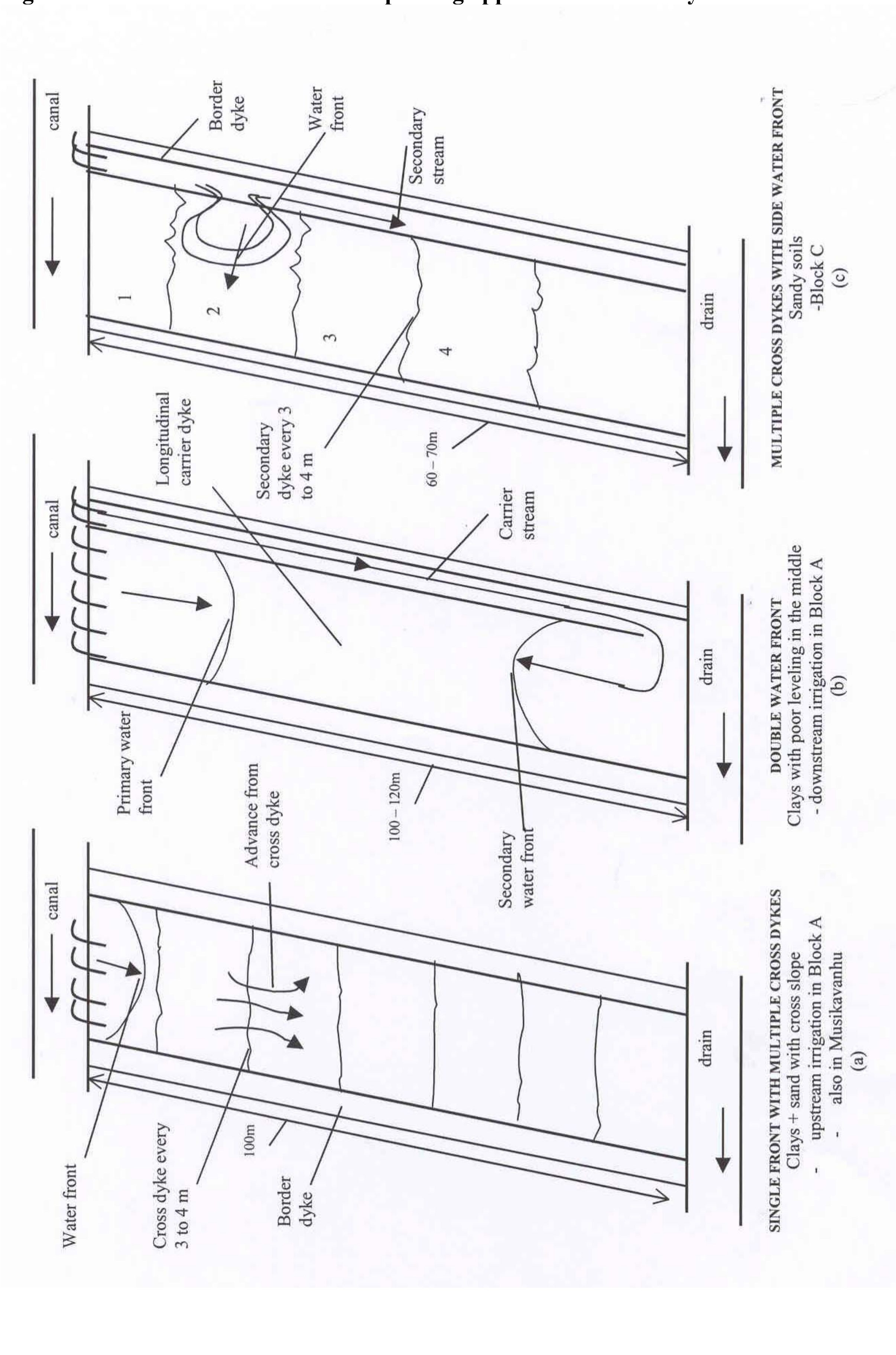
Table 3.5.3: Crop Planting Date and Area Planted (bunds) in Early Winter 1999 .

Block	Crop	Mar	Mar	Apr	Apr	May	May	Jun	Jun	Jul	Total
		1-15	16-31	1-15	16-30	1-15	16-30	1-15	16-30	1-15	
A	Bean	39	219	239	126	31					654
	Tomato	10		10	18	0	6	9	0	5	48
	Onion			22	0	0	0	0	0	1	23
	Wheat						8	3	0	14	25
	Okra									4	4
B	Bean			173	355	44					572
C	Bean			61	210	302	96				669
	Tomato									18	18
D	Bean			76	67	81	44	26	0	60	354
	Onion							3			3
	Wheat							10			10
	Peas						3				3
Source: Field observation											

At Chakowa, Samakande observed during this period in 1999 a lot of night water distribution activities as given in box 3.6.1[18].

[18] In Zimbabwe the current designs do not provide for night irrigation. It is considered dangerous due to lack of lighting, and also inconvenient for farmers. n practice the farmers use night-time flow as extra capacity to catch up if the delivery system allows. Night irrigation is often unpopular because of some strange things that are believed to haunt the fields at night. Its not clear whether this is a true phenomenon or is sustained as a social means of restraining people.

Fig 3.5.2 Practical methods of improving application uniformity at Chakowa



Box 3.6.1 ***Operation "fill night storage dam for C Block irrigation – no bypass abstraction, no illegal gardens"***
The research student in Chakowa recounts how one night a group of men from block C came to the night storage dam at block A. They chased away the farmers from the lower end of block A that were bypassing the NSD to irrigate their plots at night. These main block A farmers were bypassing the NSD by siphoning water from the conveyance canal, just upstream of the bifurcation that split night flow going to the two NSDs, into the canal that leads water to the main Block A during the day. This would allow them to get water to their downstream block without it being diverted upstream. The Block C "farmers" placed some of their members to guard the operations at this upper night storage dam (NSD_1). The main body of the group then followed the 5 km canal length between the two night storage dams. On the way they chased away illegal garden abstractors. They ensured that there was adequate protection left in the process. By doing this they ensured that the night storage dam (NSD_2) was full the next day. Some of the men who took part in the "operation" were paid by women who were afraid of this nocturnal water acquisition activity. Block C and D took turns to irrigate using the NSD_2 water at peak times. The water commandeering operation continued every second day to ensure that the groundnut and maize crop in block C were saved. The farmers claimed that they could not have food for their families without such an operation.

Water bailiffs at Chakowa monitor irrigation turns. The head-enders have many more turns for a longer time, with frequencies of 7 days for upstream farmers in block A, as compared to the tail-enders whose frequencies vary from 8 to 14 days as shown in table 3.3.1. The actual number and time a farmer receives an irrigation turn is determined at block level. At peak demand irrigators in block A have alternate dry and wet days between the head-end and tail-end. The major problem though is that the tail-enders cannot police the arrangement and therefore lose out to theft. Some farmers have abandoned plots due to this problem. An agreement to closely monitor water use and turns in this block resulted in the water bailiff being the first to be fined because he had forgotten to close the canal gates overnight[19].

The number of turns a farmer gets depends on the crop. The early vegetable crops get the most turns. The main crops maize and beans get an average of 6 to 8 and 4 to 5 irrigation turns per season respectively.

3.6 THE REALITIES OF OPERATIONS AND WATER DISTRIBUTION

At peak abstraction the scheme is recorded to take in 112 $l\ s^{-1}$ as gauged at the DWD flume near the intake but this can decrease even to zero flow in the low rainfall years. This flow is not gauged again before it gets into the night storage dams or distributary canals. The farmers rely on Agritex water bailiffs to distribute the varying flows of water across the four blocks. Water bailiffs have been involved in water distribution at Chakowa since the scheme started operating. The EW and water bailiffs do not have any written strategy of distributing the varied flow. They do not have records of flow variation[20]. So how is distribution practised at Chakowa?

Water bailiffs have no operational rules to set the gates, except their experience. While the water bailiffs do take gauge readings, they rarely stay in the location: both water bailiffs have plots in Block A. They come in the morning to set the gates and reappear to reset or

[19] When other blocks heard of this event they complained that the new Chairman was only doing a good job in his block. Incidentally both water bailiffs and the new Chairman were farmers in block A.
[20] Both Vos and van der Zaag have shown that flow measurement is not a necessary condition for good water delivery performance (Vos 2002, Zaag van der 1992).

close the gates in the afternoon. They remind the next irrigator that after the one irrigating their turn is coming. An irrigator does not have a predetermined time to complete irrigating because fields are different as regards soils and land levelling. "*Minda yakasiyana ivhu nekurevhurwa saka imweni inononoka kupera kudiridza kana isina kugara zvakanaka". (*The fields have different soil and were levelled to different degrees so that those fields that were not well levelled take longer to finish irrigating*).*

Upstream farmers adjust the gates to irrigate their okra and tomato crops. It is up to individual farmers from downstream, to police and monitor so as to irrigate. While the water bailiffs have powers of sanction, this is now rarely done due to fears of witchcraft. One public secret story constantly narrated by both the EWs, farmers and water bailiffs related to a water bailiff who died after a farmer issued him a stern death threat. This water bailiff is reported to have denied a farmer an allocation because the farmer was alleged to have stolen some water. The farmer told the water bailiff that if their bean crop wilts and dies then the same would apply to him. True to pass the bean crop wilted and died and unfortunately the water bailiff died too soon after an illness. The EWs and water bailiffs used it to illustrate their powerlessness. Incidentally both water bailiffs are locals and both are farmers in block A. This story served both to warn them and to protect them from danger that could befall them if they tried to enforce rulings by either the EW or the irrigation committee.

Sympathetic farmers would always try to defend them when ever a problem of water distribution pointed at them. They tried to ensure that if a fault or control was enforced it would never lead to a direct confrontation between the water bailiff and a farmer. Either the EW or a committee member had to be present or responsible for any sensitive control or regulation activity carried out by the water bailiff. The main response of the water bailiff when confronted with sensitive issues is to report it to the EW and CMIC. These bodies can then give instructions and even provide an escort to ensure that the enforcement of control or regulation is not seen to be the water bailiff's personal action.

Block D farmers seem to be the worst hit by the distribution practice. During the critical period the gate plate for closing off supplies to block C tended to disappear. This resulted in block C sharing water with block D on the alternate day that block C is supposed to be dry. The farmers in block C would be "forced" to irrigate their plots to avoid wastage of a precious resource coming to them on the wrong day. Even the valve control to the night storage never works well when block D is retaining night flow. This valve control was vandalised but there are some clever farmers who can close it off especially when "Block C men" are harvesting the night flow as explained in box 3.6.1.

These water distribution dynamics and technological concerns shape wider social dynamics. This section ends with some of the everyday outcomes in inter-block relations from these controls: the next section looks at how they shape actions necessary at the weir. During the irrigation season, Block C still struggles to get water, through group action to command strategic technology near the NSD, especially against legal and illegal irrigators in block A. Given the system layout, Block D farmers can at best only share the water reaching strategic points in block C. They have lower cropping intensities but have developed marketing strategies to share the wealth of block A (and beyond). Boxes 3.6.1. and 3.6.2. illustrate these dynamics.

The lower blocks cannot grow okra because of their low fertility sand soils, and also could not grow an early groundnut crop because of their poor water supply. Downstream farmers may share the same canal but with almost 3km of distance upstream to control points, it is impossible for individuals to police it without a strong institutional support. All the way any upstream farmer can steal water.

Box 3.6.2 ***If you cannot grow okra- market it***
I witnessed an encounter between a popular head-ender farmer *mbuya* V and a farmer from the tail end block D. *Mbuya* V was busy weeding her early summer okra crop when a woman arrived to buy okra. She immediately stopped her operations and they teamed up to harvest the okra crop. After filling some 4 baskets (*matengu*) they stopped and measured out using 20 l tins. The woman paid up and *mbuya* V helped her carry one basket on her head. She was going to return twice to collect the remaining okra. When she was gone *mbuya* V explained that in fact the woman was a plotholder in block D. They could not grow okra there because of poor soils and lack of water. They therefore had to engage in marketing okra they bought from the head-end farmers. This particular lady transported okra to Mutare where she would resell it at twice the price. In her view the tail-enders were disadvantaged with respect to both light soils that were unsuitable for okra as well as water. This was unfortunate but really she could not do much about it. If only they could carry their fields to the head-end. Some can have two okra crops. These farmers admit that while the okra is a viable crop it is also a gross feeder. The crop requires very fertile soils preferably anthill (*churu*) that is heavy clay. This fertile soil would then require generous fertiliser application of both basal and top-dressing. Top dressing is required after each picking. Picking can be done every third day if it is sunny which favours flowering and fruit formation. Each fertiliser application event requires an application of water to facilitate fertiliser uptake. The requirement for this frequent watering is the one factor that resulted in the crop being concentrated in the plots near the night storage dam. The need for fertile soil has helped to restrict okra cultivation to the heavy soils of block A.

Irrigation in blocks B, C, and D generally starts early around 0600 in the morning and ends by 1300: very few farmers irrigate in the late afternoon, for a combination of factors. The blocks are small and the sandy soil texture requires use of higher flows and faster irrigation, thereby speeding up the rate of emptying of the NSD. This shorter irrigation time coupled with longer irrigation frequencies results in less water being applied to these downstream blocks compared to the head-end blocks. This leads to lower productivity - and farmers' adoption of deficit irrigation or stress avoidance strategies like planting only when the rains come and restricted cropping in winter.

What options then are possible for change? Besides trying to reinforce Young's level of discipline in order to save canal embankments especially at the upstream section, one can also consider redesign during rehabilitation. The canals supplying the downstream section could be designed in-cut so that upstream farmers cannot steal water from them on a continuous basis. This approach is likely to increase total lengths of canals as this implies constructing field conveyance canals parallel to irrigating canals for small areas that can be supplied with dual-purpose canals. However it will also impact on equity and make it possible to apportion maintenance responsibilities to the upstream and downstream farmers[21].

3.7 FARMERS AND MAINTENANCE

Given the presence of a gang with historic responsibilities in maintenance, even though now inadequate, the farmers' involvement in maintenance is erratic. In practice, they participate in the areas that are essential to direct water delivery. Farmers have teamed up with the Agritex gang in emergencies to unblock the siphon. The night storage dams have had emergency de-

[21] The failure of block A upstream and downstream farmers to find a solution to equity problems suggests that the option of enlarging the supply channel to allow downstream blocks to share the flow as practiced in Deure (ref chapter 4) may not work at Chakowa. The current society attitude needs to radically change so as to allow for more cooperation.

silting, for example in 1992 the lower night storage clogged after a heavy storm. It is, however, the weir that gets most attention.

This section gives an overview of past practices at the weir, and then the events that took place after Cyclone Eline. These events show clearly how injustice in water distribution (which is a function of poor technical and social control) resulted in poor collaboration and participation among the different blocks of the system.

In all the years I worked in Manicaland that is from 1987 to 1993 and on my subsequent visits up to 1997 I was convinced that Chakowa was a "perfect scheme"[22]. I was only involved in the emergency desilting of the lower NSD after a 109 m^3s^{-1} flood in 1993. When I started looking in depth at Chakowa in mid 1998 the very first issue that caught my attention was the weir and its individual significance and importance to sustained irrigation at this scheme. Each time I called on the scheme the female extension worker (EW) would come up with one or two issues related to the weir for discussion and consideration. Normally she would talk about the weir before any other issues. She persistently talked about the need to frequently desilt the weir

Regulating flow into the canal

The farmers always responded positively to work for regulating inflow. They would religiously gather at the weir intake whenever the female EW summoned them. The chairman, the female EW, the local Agritex Chakowa scheme based builder, the foreman, some elderly men and a number of young men and boys regulated flow at the weir entrance on a number of occasions (as shown on the cover page). At the end of March their main concern was to restrict the flow diverted. Records show that a mean flow of 4 m^3s^{-1} is flowing in the river during this period and only 112 $l\ s^{-1}$ is required. The farmers would therefore narrow and restrict inflow to the left side. They added sandbags, stones, sand and mud to the intake in order to restrict the flow into their diversion canal. In August and September they would increase the flow by diverting and virtually cutting off all flow downstream of the weir. As explained earlier the mean flow of about 48 $l\ s^{-1}$ at this time is below the required flow of 112 $l\ s^{-1}$. During the regulation process the farmers simply used their experience and argued with each other until the diversion canal was flowing full.

Weir maintenance-surviving the 1999 flood damage

During the 1999 heavy rains, a tree clogged the weir intake, resulting in throwback and overtopping of the sand "island" river training or earth bank shown in photo 3.3.1, leading to erosion and eventual collapse in two points on 31 May 1999[23]. The farmers gathered and deliberated on the issue. They resolved to cut off the branches. Some tried burning off the log but failed. The earth bank, that separated the main river flow from the diverted flow, had to be repaired urgently. Eventually it was agree to obtain shutter boards and patch up the broken portion some 20m from the half weir by use of concrete. During construction water would be held back using sand bags. Farmers contributed each a bag of cement and labour. The Chairman volunteered to ferry the required sand using his lorry. Agritex provided stone aggregate and the local Agritex builder and some local farmer–self–employed builders did the works. The exercise took some two weeks and it worked. The scheme therefore worked well in 1999 with frequent patching up occasions using mainly sand bags. Although generally the weir and sandy island assembly had been weakened, it continued to provide the scheme and the farmers with the most important item to their livelihood that is water.

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[22] One would always observe the asbestos cement canal discharging water into the main road crossing and on looking west immediately catch a glimpse of good crops in the adjacent block before or after crossing the Umvumvumvu river bridge. There was an air of tranquillity.

[23] The flood of 1999 was 85 m^3s^{-1}. While it was not so big it certainly caused the farmers some discomfort. The earth bank shown in photo 3.3.1 was viewed as an island because as one walked over it to the entrance the masses of water on both side and its vegetation gave the impression of an island.

To all farmers the weir was the meeting point. Most work at the weir was done very early in the morning. Meetings were not very frequent but they existed. **The weir was therefore every Chakowa irrigator's responsibility.** The farmers were supposed to pay the maintenance fee, but at that time only the maintenance foreman was paid up for his self styled field[24]. The farmers were aware of their payment records and the value of the maintenance fees to their endeavours. When they needed to repair the weir they requested physical cement bags as contributions not cash. At this time the cost of a bag of cement was already more than the annual maintenance fees paid per hectare**.** They did their own recording and accounting. There were threats of denying water to those who failed to supply required physical materials such as cement or provide repair labour. Even though the illegal gardens were condemned some illegal gardeners came to work in order to retain their share.

The behaviour of the farmers in these maintenance works is consistent with those of simple technology FMIS. Specific attributes are: use of actual material contributions; own register of attendance; own accounting and application of sanctions related to water allocations that started in the early 1980s (Parajuli 1999, Turral 1995). The question is whether the scheme with its management support system (MSSS) could survive larger river tribulations without government or other external support.

The cyclone Eline experience: Chakowa weir rehabilitation

The February 2000 cyclone brought Chakowa irrigation scheme to a total standstill because the entire intake weir "island" was swept away. The high flood swept clean all abstraction structures that were not well founded. Magobeya's sediment free intake weir was also razed to the ground. No evidence was left of the grassed sand island. The old river trainings just below Magobeya's weir were not severely damaged. They were used to keep the main river flow to the right and thus avoid excess flow into the canal diversion. A portion of the half weir was also knocked down. There was also a massive deposition of sand and silt, which made the wall yield, as it had not been designed to bear such a load. The massive sand, silt and boulder deposition extended well beyond the desilting basin. Beyond the half weir portion the cyclone-induced floods altered the river channel completely. The main river started meandering towards the supply canal and de-silting basin making it an active erosion zone with the danger of further undermining the supply canal.

The desire to save the lucrative bean crop was the major driving force for the farmer's effort to repair the intake quickly just after the cyclone. The farmers decided to repair the intake themselves. Table 3.7.1 highlights some activities and agencies that were involved in repair works in year 200 when the field work for this study ended. The farmers initially removed all the mud that blocked the intake and supply canal. The first part involved desilting the supply canal. This was target based *(mugwazo)*; and starting from the 80m chainage from the intake structure to the flume, each farmer was allocated a metre to desilt. From the 350m chainage each a farmer had to desilt three metres. Some farmers hired hands to do their portions. One local person actually expressed gratitude "*paya takambo rovha mari*" (during that time (desilting) we made a lot of money). The desire to plant the bean crop forced the farmers to cooperate and work at a fairly acceptable pace.

The weir reconstruction involved farmers erecting a wall by hipping stones that they took from the river. The stone wall almost cut across the river channel at an angle of about 60 degrees to the river. It was done under the instruction of Mr T. some local 'dam specialist'

[24] The maintenance foreman said that he constructed his field alone and added it to the scheme as an extension. He did the land levelling by hand for his 0.4 ha plot. There is no formal supply from the scheme and therefore he abstracts water by siphoning from the main canal into a secondary earth canal. He is at the top end of block A. After his plot was formalized he then moved to reside in Chakowa some 20 years back.

who told them, "*mvura inoda kunyengeterwa*", (water has to be negotiated with). At first this seemed quite encouraging as the head seemed to rise, but the water never got to the intake level. When this effort failed to get the water moving other political dynamics started to take place. This frustrated the farmers and quickly turned them into vulnerable dependants. Some highlights of events during the repair are summarised in table 3.7.1.

Too much maintenance stress-political affiliations and social disruptions

When the cyclone struck and the farmers failed to get back to irrigation as hoped, the inequalities between the blocks started to emerge as people started to air their grievance more openly. The main break from the tradition of silence, as well as from normal cooperation in repair works, came from block D and C water users. These divisions centred on soil productivity and the "artificial" inequalities in water distribution and allocation.

Table 3.7.1: Summary of highlights of events during Chakowa major weir repairs

Date	**Attendance**	**Work done**	**Social organiser**	**Remarks**
03/07/2000	65/124	Collect stones	Farmers, local Agritex	Meeting held first to get Chief irrigation officer commitment to lead repairs, headman requested to mobile farmers.
26/08/2000	75/124	Completion of laying of gabion mesh wire, start on sand bags	Farmers & student research assistant	Farmers gaining confidence due visible water level rise on adding sand bags.
31/08/2000	High	General meeting on importance of canal to society e.g. dip-tank, moulding bricks, "illegally" washing and bathing.	Headman	"Illegal abstractors" join in repairs due to threat of no water in future & burning down gardens by plotholders.
Weekend (of 26/08/2000)	10 hired men	Laying sand bags	Local Agritex & research assistant	Paid $5000 by son of maintenance foreman.
Source: Field Observations and personal communication				

The people at the tail end of block complained about injustices but they came for repairs at the intake. The block C and D farmers eventually stopped coming for weir repair altogether. They claimed that the cyclone had evened out their injustice "*Tose tafanana*". Some farmers in block A did not share the same sentiments. In their view the people from block C and D 'are lazy and jealous, that is why they do not want to come and help us repair the intake' (*"Vane ushomvu vhanu veku namba three ne four, ndizvo vasi ngadi kuuya kumugero kuzo shanda"*). However some farmers were acutely aware of this fertility difference and its significance, and sarcastically sympathised with these farmers who took up marketing of their okra as they had inadequate water for their own livelihoods.

Politics and political affiliations also surfaced as a stumbling block. It was alleged that councillors and some other political leaders were aligning their supporters towards certain canal repair activities and perceptions. Some say that the local Agritex officials were not spared. Some claimed that some politicians had made promises about canal repair in their campaigns that they had obligations to fulfil.

There were internal warnings notably from block A headman of a need to dissociate politics from the livelihood issue of irrigation " *Mukada kusanganisa nyaya dzepolitics nedzemugero, hapana development yamunombo wana, kana mada zvemugero, itai zvemugero* *musiye politics dzega*" (If you want to mix intake repair issues with politics there won't be any meaningful development, so worry yourselves about repairs and leave politics aside).

One headman strongly encouraged the community to come for repairs at one funeral "*Munu wese arimugari wemuChakohwa, unganyari ane eka, kana asina, unofanirwa kuenda kumugero. Munu wese muno unoshandisa mugero, kunganya kudhiridza garden, kunwisa mombe nembudzi, saka munoto fanirwa kuuya kumugero*"[25]. (Everybody who resides in Chakohwa is supposed to come for repairs, regardless of whether he/she owns a plot. Everybody who either uses water in the garden or watering cattle or goats should simply come for repairs). Some people related the contribution of particular villages to repair issues to the leadership and perception that the headman gave.

The community is believed to have conducted a ritual ceremony to cleanse the community of a bad spirits to facilitate the repair work. The aspect of associating any mishap with evil spirits is endemic in Zimbabwe. The involvement of local leadership both traditional and political in intake repair issues and the perceptions relating to misfortunes and various society interpretations have been observed and documented in other schemes like Mutema and Nyamaropa (Vijfhuizen 1998; Magadlela 2000). Mollinga using experiences from India argues that power politics is an important part of the irrigation discourse (Mollinga 1998).

The problematic repairs at Chakowa resulted in farmers losing not only their first crop immediately after the cyclone but a number of cropping seasons. An informal survey showed the range of ways in which farmers' lives changed, as highlighted in table 3.7.2[26].

3.8 DISCUSSION AND CONCLUSIONS

The contributions in labour at the Chakowa intake are consistent with practices in Mexico and Nepal as reported by van der Zaag (1992) and Parajuli (1999) respectively. Farmers seek to avoid involvement in water distribution, but will get involved in cleaning canals and effecting repairs that affect their water supply. The pulling together of agency and farmer resources is also reported in crisis situations by van der Zaag with farmers pressing ahead before agency responses (van der Zaag 1992). However, inequalities in everyday access to water do affect prospects for group action to resolve system level problems. The problems at the weir seem to be a culmination of issues, including declining support from government and flood damages beyond the capacity of the local community to handle, especially with internal divisions consequent to inequity between blocks.

The problems of cross-block inequity have been increasingly documented since 1980, for example also in schemes like Nyanyadzi. Prior to independence, the main solutions were sought through construction of night-storage dams, enlarged supply canals, locked flexible gated division structures and between block rotations, all with strong institutional control.
The main design recommendation since that time has been that design should provide for proportional distribution of water to small blocks, below which farmers' groups take charge of sharing water turns (Tiffen and Harland 1990). This has been largely the main official reason for adopting the Fayoum weir documented in chapter 6 Musikavanhu case study. However, no new solutions have been brought back into Chakowa. We see the MSSS also

[25] One "*eka*" refers the having an acre plot in size. In Chakowa and other schemes the word "*eka*" actually refers to anyone who has a plot of any size. The average plot size is 0.8 ha in Zimbabwe. An acre (0.4ha) was the smallest area allocated by irrigation managers. This may have been the basis of the use of "*eka*" to refer to ownership of irrigation land.

[26] The fieldwork for the study ended with the Chakowa intake repair issue not concluded. It is however understood that eventually a diversion structure not radically different from the others restored flow to the scheme around October 2001.

unable to cope with current management or ideas to reform siphon practices or illegal gardening.

Table 3.7.2: Some examples of disruption due to cyclone Eline at Chakowa

Enterprise	**Activity /Standard**	**Before Cyclone**	**After Cyclone**	**Remarks**
Grinding mill-Lister TS2 engine	Diesel used per day	20 litres	5 litres	Maize actually bought in from surroundings because Chakowa irrigators sold off entire crop as green mealies anticipating normal harvest.
	Earnings $/day	8000	2000	
	Maize per family per call (average)	50 litres	5 litres	
Radio and TV repairs		Repair items paid up at collection	Items not paid or collected	
Livelihood Strategy		Irrigation farming main activity	Bird catching main activity	Irrigation overshadows other activities eg Bird catching.
Market vendors		Sweet potatoes Sales high, cheap tomatoes from Chakowa dominant	Low sweet potato sales, high priced tomatoes from Mpudzi	
Sales okra and groundnuts	Earnings per family	Average $3000 per month at peak	No sales	Most farmers equated this to losing a job.
Source: Field observation				

Cross-block inequities in water access will undermine any attempts by an IMC to collect even existing maintenance fees. Also, unlike other systems in this study, the central IMC plays no role in crop marketing, as Chakowa location facilitates individual strategies in buying and selling. Individually, the two headmen have exhorted their communities to take part in weir repairs. However, the division in water availability across the scheme is largely echoed by the division in territorial responsibilities between them. The IMC is now headed by a block A farmer: the previous Chairman from Block D was already involved in marketing as an additional livelihood strategy to compensate for fewer crop options.

There has also been a marked change in the operation, maintenance and authority structures in Chakowa. The net effects of these changes have been a significant decay in scheme maintenance and poor operation as documented in this study. There is no clear line of authority at Chakowa. The few agency personnel remaining at Chakowa are charged with the operation and maintenance of the lined supply and cross block distribution canal that they cannot cover. No review has been made of runoff problems for an environment of increasing settlement.

When the Chakowa scheme was structured and engineered by Alvord and Young they each had a clear institutional arrangement for the scheme. This study revealed that the community actually cherishes and almost glorifies equity during the days of Young's management. The study also reveals that the water supply and weir repair problematic is beyond the capacity of the farmers, local government institutions and those directly in control of irrigation. Even politicians are not in a position to provide solutions, even though some seem to have touched on the possible leverage interventions. There are also policy and control issues that have to be structured in order to find enduring solutions for Chakowa. A case in point is that dam construction priorities along the rivers have never been based on the established needs of existing smallholder schemes after independence.

The handover process of the system was not clearly planned and as a result, issues that should be left with government have tended to be turned over by default. The farmers have demonstrated capacity to handle minor operation and repair issues. However this capacity has tended to be misconstrued by outside designers as reason to perpetuate the current weir design concept to the detriment of the sustainability of the scheme. Designers have tended to go for "quick-fix" options of maximising farmer participation, without taking care to synchronise the farmers' local capacity for O&M to the designed artefacts and their vulnerability to the local water regime.

Leveraging at Chakowa

Very clearly, the Chakowa system is not working well. While Young tried to address this issue by reducing the scheme size and building night storage dams, the problematic has persisted. The irrigation leader's job in learning institutions would now be to advocate and align staff to see the leverage in this intervention (Senge 1981).

This study suggests that the two major MSSS features at play, the forces of markets, and the current transformed institutional structures, will not themselves re-stabilise the system. What options exist then? Any structuring or engineering of the WDSS interventions at Chakowa need to take account of this production and marketing MSSS and retain or improve its contribution to equifinality. The MSSS on the other hand should be fully utilised as appropriate in rethinking the WDSS to meet service objectives. Designs need to consider cost effectiveness at Chakowa, and take account of the MSSS financial contribution - especially to get all farmers to contribute to fee levels as appropriate - and the power of the MSSS to enforce cross-block equity. More widely, profitable crops for sandy soils are also an issue. The WDSS alone cannot provide the security, reliability and water control required to ensure equity at Chakowa. The farmers' observation that surface irrigation cannot control and apply small depths of water is scientifically correct (Horst 1998). This is what they need and they cannot get as evidenced by the high uniformity achieved with low efficiencies.

Beyond rethinking fees, representation and equitable access, other main future points of leverage for Chakowa are: stabilisation of supply**,** provision of a permanent abstraction point and improved water control at field level. Most of the problems seem to be emanating from scarce and unreliable supplies that cannot be managed. Stabilisation of water supply has been prescribed as a solution for such situations (Horst 1998). Options open to the Chakowa system are construction of a dam on the Umvumvumvu, pumping from the nearby Odzi River and use of groundwater. However, the last two options brings costs that may be too high for these farmers to bear, as case studies from Mutema, Bonde and Musikavanhu will show. The starting point for change at Chakowa, so long thought of as an effective irrigation system, is for a new debate between farmers and engineers, on what farmers want and can manage.

Control of water at field level will also be required taking note of the different soils and community cooperation and system resources for operation and maintenance. Some further insights from the chapter 5 to 8 are required to inform the reflection and choice process.

4 DEURE: PROPORTIONALITY AND EQUITY IN BLOCK ROTATION

4.1 INTRODUCTION

The Deure irrigation scheme was started 1936, and it is believed that Alvord was requested by the Chief Chamutsa to come and peg a canal from the Deure River. This was as a drought mitigation measure and also in recognition of the achievements that he had made at Nyanyadzi and Chakowa. Box 4.1 gives more of the oral history of the start of this scheme. Alvord identified a weir on rock foundations and pegged an 8km canal to the present Deure scheme. The early scheme had persistent water shortages. At one time sand abstraction pumps were installed near the Deure and Save River confluence to supplement canal water.

Box 4.1.1: History of Deure scheme development according to Mr. Maparara

What really started the idea of having a canal dug? There was hunger here and old men and the Chief (referring to the traditional Chief Chamutsa) approached Alvord at Nyanyadzi. The white man promised to come to survey. When it was time to get people for digging the Chief requested for people from each headman from Murambinda, Buhera, Chamutsa and Nyashanu. Their respective headmen forced them to work a practice called c*hibaro* that is also reported for Chakowa in chapter 3 and Nyamaropa (Magadlela 1999). Each person was requested to work for three months then another group was supplied. They got paid a little sum of money. They were given food like groundnuts, dried fish, beans and maize. Cattle were always ready for slaughter and some people were cooking while others were working. After a day's work you got food. Government provided tools and dynamite. Mr. Maparara himself worked with dynamite. They drilled by hand to make holes. They would then place the dynamite, fire it and run away shouting "danger!" Each day one drilled three holes of three feet each, and it was hard. They were not on a three- month period as some were not easily available. At the intake they really suffered. From the development of irrigation no one has gone out to look for food in the Chamutsa area. Previously they survived on a wild fruit called *icha*. They would dig a hole in the ground; put fire in the hole and green leaves of the *mupanda* tree to avoid soiling the fruit. "I am talking about hunger here" he emphasised. They then put the *icha* fruit and closed with an iron sheet or tree branches and then closed tightly with mud to create an oven. They would light a huge fire with *musasa* trees and keep it burning for 24 hours. They were then opened and people took the fruit with buckets for storage. People would each eat this *icha* and drink water. "We were only helped by Alvord", he concluded.
Source: Field interview 1999 (translation from Shona)

In 1976 the government constructed the Ruti dam on the Nyazvidzi River upstream of the Deure Scheme. Since then the scheme has had a reliable and secure water supply for most of the year, although cropping patterns still create situations of relative water scarcity. In 1985, there was a consultancy study of Deure to look at rehabilitation needs (similar studies were carried out for several schemes to assess the damage caused by the liberation war that ended with independence in 1980). It identified three areas of technical intervention: lining the main canal, lining infield canals and construction of a night storage dam (GKW/HTS/BCHOD 1985). The lining of the infield canals was adopted as the first intervention in the period 1990 to 2000 on the advice of local staff, and in 1974 the main distributary canal was lined, but there was still some competition for water due the way all blocks planted crops on similar schedules. In 1991 the intake for the Bonde lift irrigation system was started next to the Deure weir intake (see chapter 7). It has affected attention to the weir – water supply to the Bonde pumps necessitates frequent desilting of the weir: however as the systems share Agritex staff, the importance of Bonde might have had some impact on the management support sub-system. The Deure system has some 300 hectares in 7 blocks, all developed about the same time. The configuration of offtakes and gates means that all blocks share in any deficit in supply.

Scheme management has changed among government institutions over time. There has been a general decline in support provided to the farmers, but much less than at Chakowa. The Deure farmers have responded by appropriating the maintenance of the water delivery assets that directly affect their livelihoods, including the main canal, and field canals in Block A. The Deure farmers started like all other earlier schemes with a complete government sponsored cropping package comprising a cropping program of maize, cotton, wheat and beans with inputs, market outlets, and penalties and rewards that linked up water use, discipline and the water delivery system care. Local government put in place an appropriate management institution with an irrigation manager that controlled the daily activities of farmers and government staff at the scheme.

The scheme is on a main road junction to the towns of Mutare, Masvingo and Chipinge and farmers now grow green maize, tomato and groundnuts for the market, at the expense of cotton. This gives a sharp peak water demand, created by early planting of maize and groundnuts, almost resembling monoculture. The farmers' practical response to this operational problem has been to take a leading role in the allocation of water across hydraulic blocks thus allowing frequent but short irrigations resembling what Horst referred to as "pulse irrigation" (Horst 1999). The stable water delivery at Deure has allowed all scheme members to enter the market.

The underlying institutional structure at Deure has seen a central and stabilising role played by the traditional leader. The Chief was involved right from the beginning and has been playing a role in the affairs of the scheme throughout its history both as a farmer and a member of various institutions[1]. This role has partially substituted for the lack of authority left with the various institutional reforms that have crippled other schemes like Chakowa. The current role of the Chief is mainly focused on plot allocation and discipline. The internal hierarchies of this staff and their more effective interaction with the extension staff and IMC all help the scheme to better performance in operation and maintenance – although there is still room for improvement.

While the Deure scheme generally presents the same core technologies that are discussed at Chakowa, there are some significant differences and interventions that give it elements of equifinality or sustainability. The water delivery is stabilised and secure due to the dam and weir founded on rock, having fewer flood events and less siltation problems. The simple earth canal is amenable to farmer management. It also has a system of gated controls that help effective rotation between blocks when water is inadequate which are also well secured against theft. The distributary canal offers the flexibility needed for farmers and the local support institutions to exercise equity during the peak demand period. The local extension members have a clearly defined role in water allocation at block level, and also play a leading role in mobilising and co-ordinating all institutions involved in the scheme's well being. The constant presence of the traditional authority has stabilised the institutional arrangements. The main weaknesses at the scheme relate to poor maintenance of structures not directly related to the water delivery, waterlogging in most blocks, poor attention to health-related issues and poor institutional support to the irrigation management committees.

This chapter first outlines the hydrological environment of the scheme, and key production aspects. Later sections then present the operation and maintenance at each of the core levels of the scheme in turn, and the fit therein between technology and management. The study shows how the Deure community - farmers, traditional leaders and local

[1] The name Chief used here refers to the position or function not the incumbents.

government agents - is responding to changes by adopting and adapting both technical and institutional structures and responsibilities, although weaknesses remain in maintenance and institutional support. The chapter concludes on the leverage necessary for water delivery service improvements at Deure.

4.2 HOW A STABILISED WATER REGIME BENEFITS PRODUCTION

Currently, the bulk of irrigation water for Deure irrigation scheme water is a direct abstraction of the summer river flow. The supply from the Ruti Dam on the Nyazvidzi River (90 km upstream) has resulted in a marked increase in the security and reliability of the flow: records, with a marked reduction of days of no flow after 1973. The mean minimum flow of 2.18m^3 s^{-1} is double the required canal capacity at the weir diversion of 1 m^3 s^{-1} (1000 l s^{-1}). There is variation from 2 to 67 m^3 s^{-1} with an instantaneous peak of 1260 m^3 s^{-1} in 1980/81 indicating a significant variation in sediment carrying capacity of the river. This has a significant impact on the siltation of both the weir and canal and shapes the maintenance requirements.

The current water right provides for the abstraction of 283 l s^{-1} from the Deure River and Ruti Dam. The scheme gets water by making requests to the DWD through the Mutare office. When the river is dry it takes almost a week for water to travel from the dam to the scheme: with natural base flow the dam water takes 3 to 5 days to reach the scheme. There is no clear procedure for requesting water between Agritex and the DWD. Farmers clearly expect water to be requested by Agritex.

Before the 'team approach' in 1998 the Agritex extension officer stationed at Deure irrigation scheme was responsible for the overall management of both Deure and Bonde irrigation schemes[2]. Water bailiffs and the Senior Water Controller visually monitored main canal flow levels and submitted requests for additional water to the officer via the supervisor. The Agritex officer phoned the DWD attendant at the intake to request for water from the DWD Mutare Office. The request specifies the date the water is expected but no quantities were given. For longer-term requests the Agritex supervisor phoned the Regional Water Authority (RWA) office in middle Save to request for water around May or June[3]. The dam would release water until October or November or until the rains came. In this case neither dates nor quantities were specified in the request. According to a former Agritex Deure officer, the DWD knew how much to release from experience[4]. During his time requests were made through the Agritex District Office or if urgent direct to DWD: they specified only that they were short of water.

Agritex and DWD (ZINWA) staff members are still adjusting to the need to specify water releases to suit crop water requirements. Engineers still use the standard allowance for crops in existence from the 1950s. This has probably remained the same since water

[2] In the late 1990s Agritex adopted the 'team approach' that required extension officers and extension workers to each specialise and work as a team serving a specific geographic area. Extension activities in each area were coordinated by as team leader who was either permanently appointed as practiced in Chipinge, or there was continuous rotation as was practiced at Deure in Buhera district. This meant that the old approach of an extension agent serving all agricultural issues in a defined geographic area under a fixed officer –extension worker relationship was dropped.

[3] The RWA was a parastatal responsible for operation and maintenance of large dam and water deliveries in the south-east irrigation zone. It has now been merged with operational functions of the former Department of Water Development, to form ZINWA.

[4] One senior DWD technician explained that the calibration of flow releases and their attenuation as they move down the river was done just after the Ruti dam was commissioned. Only a few staff members still remember the process. However the dam attendants still use those calibrations.

payments, for smallholders and all water right holders in Zimbabwe, were only initiated in 2001.

The crops grown at Deure can broadly be classified as summer and winter crops. Summer crops are generally crops planted after the cold months of June and July and generally utilise rainfall during part of their growing season. Winter crops are grown after or at the tail end of the rain season and are subjected to the cold weather during part of their growing season. The crops grown and their planting dates are summarised in table 4.2.1 and 4.2.2. Family livelihood food needs and the marketing options at the local Deure bus terminus, Mutare vegetable market and canning firms determine the crops grown. The 1985 consultancy study noted that farmers already had good yields for crops and therefore little change in cropping patterns or yields would be expected due to scheme rehabilitation (GKW/HTS/BCHOD 1985, pp1).

Table 4.2.1: Area planted (ha) in early summer 1998 at Deure

Block	Crop		Aug	Sep	Sep	Oct	Totals
			16-31	1-15	16-30	1-15	
A	Maize			1.6	11	13	25.6
	Groundnuts			0.8	1.8	1.2	3.8
	Okra					0.8	0.8
B1	Maize			2.8	18.8	21.8	43.4
	Groundnuts			1.6	3	3.6	8.2
	Okra						0
C	Maize			2.8	19.2	20.4	42.4
	Groundnuts			1.2	3.2	3	7.4
	Okra						0
Source: Field observation							

Table 4.2.2: Area planted (ha) in early winter 1999 at Deure

Block	Crop	Jan	Feb	Feb	Mar	Mar	Apr	Apr	May	May	Jun	Totals
		16-31	1-15	16-28	1-15	16-31	1-15	16-30	1-15	16-31	1-15	
A	Bean				0.8		11.2	0.8	1.6			14.4
	Tomato	0.8	0.8	1.6	2.4		1.6	0.8				7.2
	Onion											0
	Wheat								7.2	1.6		8.8
B1	Bean				0.4	4.9	5.6	1.8	0.4	1.2	1.0	15.3
	Tomato				3	5.3	2.7	1.2	0.6	1.3	0.4	14.5
	Onion											0
	Wheat						0.6	0.4	12.9	6.4	1.8	22.1
C	Bean	0.2	0.2			1.8	7.9	9.9	0.8	0.5	0.4	21.7
	Tomato	2.6	2.6	2.6		0.6	1.2	0.7				10.3
	Onion											
	Wheat								13.7	4.7		18.4
Source: field observation												

The main change over time is the continued decrease of the cotton area, already taking place in 1985. Currently only a few farmers in Block A and Block C are consistent cotton growers due to their heavy soils. These farmers also practice okra production due to the heavy soils as at Chakowa.

There is a high degree of sub-letting of plots, especially among women, in which maize and groundnuts are important crops for reciprocity in network building (see also Vijfhuizen 1998). Plots are sub-let and paid on a seasonal basis depending on the number of bunds utilised. The plot owner or *roja* (leasee) can irrigate the rented plot. Maintenance fee payment and other formal requirements are only registered under the name of the formal plot owner. Most civil servants and settlers who engage in marketing and other activities rent plots as observed at Chakowa.

Livelihood crops

The definition of livelihood crops used here is limited to those crops that are largely used for home consumption. The livelihood crops at Deure are maize, wheat, groundnuts and vegetables, although for crops like fresh groundnuts and green maize some opportunistic market niches are also starting to emerge.

Generally maize is planted early just after canal cleaning at Deure. Only a few farmers plant the crop before the 10th of September. The crop matures in December, and is sold as green maize at the Deure *musika* (market), enhancing the financial position of the farmers. However very few farmers sell off their entire crop: they prefer to retain sufficient maize for their family consumption. Normally those who sell excess crop and try to buy in to supplements become the object of public ridicule. Some use wheat to supplement maize as a food crop. The wheat crop grown is mainly for local consumption. A few farmers sell the crop to local bakeries. While wheat was introduced to smallholder irrigation schemes as a potential commercial crop it has never really been a major source of income. The high fertiliser and labour requirements erode its viability even for schemes with no pumping costs.. Besides the high input and labour requirements, the crop is not known for high income. The farmers view is that the wheat saves them financially because they do not have to buy bread from bakeries. The also make wheat *sadza*. In Zimbabwe very few smallholder schemes have successfully grown wheat at a large scale.

Deure farmers plant about 20 percent of their area to groundnuts: they are planted at the same time as maize and therefore harvested early. If marketed, the Deure crop is mainly sold to female buyers who retail it even as far as South Africa. It is not unusual for a farmer to sell her entire crop in as short a time as a week. Buyers normally prefer the big groundnut variety. The irrigators prefer these quick sales as they relieve them of work and selling pressure, and because a large sum received in a short time enables them to make good use of the money. One widow in block B1 renowned for growing groundnuts claimed that the crop helped send her three sons to boarding school.

The other livelihood crops at Deure are minor vegetables like rape, onion and cabbage that are grown for nutritional purposes. At Deure the onion crop fetches good income on the local market. However it has to compete with a bigger crop that is normally supplied from Tawona near Mutema[5].

Commercial crops

The main commercial crops grown on the schemes are cotton, tomatoes and beans. Deure like most schemes located in the arid parts of southern Manicaland province, grows two crops of tomatoes, the first for niche marketing and the second for canning. The first crop of tomatoes

[5] The smallholder onion market in Manicaland is believed to be controlled from Tawona. The sourcing of seed seems to be the determining factor.

is planted after the green maize in January and February. This crop coming in summer is subjected to a lot of damage from blight and its survival is dependent on either a relatively dry year or a good fungal disease control program. However, surviving crops can be sold for the table market at lucrative prices. The main canning crop is planted after the rains in April. Temporary flooding, that normally occurs during heavy rains in the more gentle block B, easily destroys the tomato crop due to root rot and over the years this has influenced farmers to plant later than block A and C. The tomato crop occupies up to 25 percent of the cropped land in all blocks at Deure.

Beans are the mostly widely grown crop on all large irrigation schemes in semi-arid Zimbabwe, and also at Deure. The majority of schemes grow sugar beans (*Phaseolus vulgaris*), which are bought by companies based in Harare and Mutare. Most farmers at Deure thrash their beans at home and use the stover as cattle feed. Farmers' like beans because the crop has relatively low input requirements and also a low water demand: besides pre-irrigation and harvest irrigation "*kudzurisa*" only three or four and at most five "irrigations". It is grown in winter when few alternatives are viable and is not perishable, giving farmers opportunities to hold them and bargain for better prices when possible. Farmers' transport their beans to the weighing point at Deure Agritex office where buyers then transport purchases in trucks.

These cropping patterns and cultivation practices affect water delivery. Stresses build up in the summer season for maize irrigation. However the low water consumption by the bean crop is not translated into water savings. The RIS for winter seasons show a marked higher supply over demand in Deure, as Makadho (1994) found on other schemes in Zimbabwe. In surface schemes this has largely been attributed to the system inability to apply smaller depths of water. In both Deure and Chakowa, pre-ploughing and harvesting irrigations "*kudzurisa*" can also account for the high relative water supply. Makadho also correctly pointed out that the availability of water excess to demand could significantly contribute to the excess supply (Makadho in Rukuni *opcit*, pp52-53).

4.3 THE DEURE MANAGEMENT SUPPORT SUBSYSTEM

Revisiting history: from irrigation managers to extension staff

Like Chakowa, Deure also had a tradition of irrigation managers. The last white manager was a Mr. Sprr: irrigators say that caring for the canal was a prime activity of him. He used to visit and inspect the supply canal on a regular basis. When farmers saw him driving up to the canal they would say "*Sparrow ari kundoona mwana wake*" (Sprr is paying a visit to his child). African managers replaced Sprr and the last of them was regraded as an extension supervisor. The farmers said the last manager Mr Mdy also walked along the canal once every week. He also made the care of the canal one of his main activities.

Deure is also a typical old scheme that has undergone and is still experiencing the flux in institutional arrangements that have characterised older smallholder irrigation schemes. In the period 1970 to 1991 DWD, DEVAG, DERUDE and lastly Agritex staff mostly drawn from the local area kept the canal clean. In fact gang members worked on cleaning the canal on a continuous basis, so breaks in water supply were not necessary. Some farmers were employed in these gangs. When after independence Agritex started to reduce its maintenance staff and resources, it became necessary to get farmers organised to assist in canal desilting. There were several gang members assigned to this task, and farmers only helped at peak times.

Around 1991, a lot of older gang members were retired from Agritex. Most are farmers: some are still bitter about this and say the remaining gang members are not effective in maintaining the scheme artefacts. The remaining staff were then redeployed with much emphasis on water distribution i.e. water bailiff services only. Currently there are hardly any members responsible for main canal cleaning. Table 4.3.1 summarises some of the changes at Deure between 1985 and 1999.

Table 4.3.1 Summary of extension, operation and maintenance services at Deure irrigation scheme in 1985 and 1999

Description	**1985**	**1999**
Study Area (ha)	250	340[6]
No. Of farmers	311	215
Hydraulic blocks No.	7	5
Scheme Management		
Management	1 manager	1-officer, 1-supervisor
Administration staff (Clerk and office orderlies)	2	3
No. EWs/extension officers	5	4
Water distribution-Operation		
No. Water bailiffs	6	6
No. Water controller	1	1
Maintenance staff		
Foreman	1	1
Drivers	3	3
Handymen	2	1
Fence ranger	1	Nil
Snail ranger	Nil	Nil
General hands/labourers	25	10
Equipment		
Tractors	2 functional	1 functional
Lorries	1 functional	1 not functional
Trailers	1 functional	1
Grader	1 functional	1
Cost recovery		
Maintenance fee level ($/ha)	145	145
Maintenance Fee payment record	Poor	Very Good
Source: field study 1999 and GKW/HTS/BCHOD, 1985		

Today, the extension service at Deure irrigation scheme comprises diploma holders and certificate holders referred to as extension officers and extension workers respectively. After the abolition of the irrigation manager post an officer was put in charge of the whole scheme. Extension officers' functions at Deure are summarised in table 4.3.2. They train master farmers in crop and livestock husbandry and finance, about ten to twenty farmers each every year. At Deure there were about 50 master farmers in 1999.

However, there are no modules that cover water management issues in the master farmer courses offered by extension agents at irrigation schemes. The only literature found available for the extension staff at schemes is the farm management handbook: The only copy found at Deure belonged to the resident engineer, a young university graduate in Agricultural engineering.

[6] The total scheme area is 302ha with 423 farmers. During the study the 30ha (27 plotholders) block D2 had been abandoned, and 50 ha (56 plotholders) of block BIII was fully not operational and was undergoing rehabilitation that included lining canals and land levelling.

Table 4.3.2 Functions of extension agents at Deure irrigation scheme

Category	**Description of advisory work**	**Means of Verification**	**Targets and achievements**
Agronomy	Crop choice, rotations, planting dates, seed type, fertilisers, pesticides, crop processing	Master farmers certificates	20 farmers trained per EW per year
Water manageme nt	Instruction on water bailiff operation, intake and main canal repairs and maintenance	Weekly meetings with water bailiffs and block IMC	Wednesday meetings with bailiffs, monthly with IMCs
Finance	Crop budgets, pricing	Crop budgets	Crop budgets per block[7] (3 crops per farmer)
Livestock	Ploughing, draught power planning, animal husbandry.	Master farmer certificates	Promoting supplementary feeding for 70 farmers per block[8]
Source: field observation			

In the late 1990s there was a drive to improve service delivery by Agritex using the concepts of team approach and specialisation. This was meant to be a paradigm shift from the area-based approach where extension workers and officers were said to run "fiefdoms". There was no clear guideline as to how this was to be done at irrigation schemes, but it was emphasised that no extension agent was to retain a geographical area of operation. The Deure and Bonde irrigation extension staff were classified as belonging to one cluster and required to re-organise into teams and specialisations. Table 4.3.3 shows the reorganisation that took place. The popularity of the strategy did not last and soon the old areas were negotiated back and some specialisation added as shown in table 4.3.3. Agritex has engaged in a programme of upgrading certificate holders to diploma level, in areas shown in Table 4.3.3.

Water delivery operational support

The consultant report of 1985 said "*The manager (IM) complained of being unable to prevent unpunctuality at turns and breaking of gates. At the moment it would appear easy for irrigators to play water bailiffs, block committees and the IM against each other. It is not clear from whom the water bailiff takes his orders*" (GKW/HTS/BOHOD, 1985, pp34). This study found a different situation. The extension supervisor at Deure chairs water allocation meetings held every Wednesday morning attended by all water bailiffs and the water controller. In the meetings each water bailiff gives a brief report on the water allocation and cropping activities in his block. This includes reporting on major allocation problems giving an update on new plantings from their records in personal pocket notebooks. Farmers are required to pay their maintenance fees after each crop. The clerk updates the supervisor periodically on the payment status and supplies names of defaulting plotholders. During meetings, these names are given to the water bailiffs with an instruction not to allocate water unless they paid or got a written note from the supervisor indicating when they were to be given water. The defaulting farmers are expected to come personally to the supervisor to give an explanation of their reason for non-payment.

If the explanation is satisfactory they get a note to take to the water bailiff specifying when they could get water and the specific number of water turns to be served[9]. Not everybody succeeds in getting water from this negotiation with the supervisor.

[7] Farmers are discouraged from growing more than 3 crops per season: Those with less than 0.4ha from growing more than 2 crops per season.

[8] At Deure irrigators are encouraged to keep no more than 4 oxen for draught power and 3 other cattle per farmer. Irrigators have agreed to ban the keeping goats because of the damage they cause to crops. A veterinary officer stationed at Deure helps in control of livestock diseases.

Table 4.3.3 Agritex Extension staff: Responsibilities for Deure and Bonde

Name	Qualification	Mobility	Previous Area 1998	10/1999-02/ 2000 Specialisation	March 2000 to Current
1 Kb	Diploma	Motorcycle operational	Study then C1-Bonde	Speciality Soil Conservation	C1 -Bonde
2. Szb	Diploma	Motorcycle operational	Study then - C & Deure	Animal	C1 - Deure
3. Pr	Certificate	Motorcycle - not functional	Supervisor Deure & Bonde	Farmer training	B1 - Deure
4. Nd (Ms)	Diploma	NIL	AEO-Deure	Water management	D1 & A - Deure
5. Tkd	Certificate	Bicycle	B1 & B3 – Deure	Horticulture – legumes	B3 & D2 Deure
6. Kdz	Certificate	Bicycle	B2 & A – Deure	Crop cereals	B2 Deure
7. Mr (Ms)	Certificate	New bike	A – Bonde	Horticulture	A - Bonde
8. Mgt	Certificate	Motorcycle & new functional	C1 Bonde then Dryland	Cotton & sunflower	Dryland
9. Sby	Certificate	Bicycle new	Attached to Dev. Assistant to Engineer	Farm machinery & development	Dev. &rehab. Bonde & Deure
Source: Field observation					

The water bailiff task is prioritised over maintenance duties. Whenever a water bailiff vacancy occurs a replacement is drawn from the maintenance gang. The water bailiff training is through attachment to a practising water bailiff for a period of about 3 months - a practice that is also reported at Chakowa and Mutema. At Deure each water bailiff works within a specified block and is responsible to the block extension worker. At Chakowa the water bailiffs report to the extension worker but there are no sanctions that the extension agents impose relating to water use or maintenance. At Deure and Chakowa water bailiffs work everyday of the week including public holidays but organise among themselves for days off duty, where a water bailiff requests another in a neighbouring block to take over duties: water bailiffs organise this themselves. The water controller at Deure also covers for any water bailiff in emergency. The water controller therefore acts as a senior, coordinating, spare or emergency water bailiff. The duties of the water controller at Deure are:

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[9]On one occasion an elderly woman farmer came to explain that she was being denied water by the water bailiff and her crop of maize and groundnuts had missed one irrigation and it was about to wilt. She had last irrigated a month earlier. She explained that her husband who worked in a town had been ill and as a result he had not managed to bring the maintenance fee home. She requested to get one irrigation water supply turn after which she could go in person to collect the fees herself from the husband. "*Ndipeiwo mvura yekungodiridza kamwechete kuti zvirimwa zvangu zvisatsve. Ndinobva ndaenda kunababa kunotora mari. Ndinouya nayo ndinopika please ndapota*". After a lot of assurances she was given a note allowing for one irrigation event. In another occasion an old woman came to explain how her children had had problems and that she was desperate with grandchildren to care for. She promised that she would pay up soon after the harvest. "*Ndapota ndipeiwo mvura, vana vangu vakapinda mudambudziko saka vasina kunditumira mari yemendenenzi. Ndipei mvura ndinobhadhara kana ndangogohwa shwuwa*". She was given a note to allow her that season irrigation water supply only.

- Opening and closing water outlets on the main canal for adjustment and emergencies such as breaches and floods.
- Following the main canal and checking for problems in the canal and making reports to the supervisor.
- Follows up water to outlets of WB. This is both for water delivery and adjustments. He checks opening for each block.
- He works with IMC committee and gives recommendation to avoid conflict.
- The senior controller provides information on the water supply in the river and to different blocks to the supervisor. It is this information and his recommendations that EW and IMC use to decide on the need for cleaning the main canal, placing orders for the release of water from the Ruti dam or converting to block rotational supply.

Manzungu (2001) says he never came across water controllers in the schemes he studied although they are mentioned in the Derude literature. Water controllers at Deure provide the practical means of exercising the across-block flexibility that is required to manage scarcity due to canal delivery capacity in Deure

As summarised in table 4.3.1 there seems to have been a deliberate attempt to match extension agents to hydraulic units or modules thereof. There were 7 hydraulic blocks and 6 water bailiffs and 5 extension workers in 1985 and 5 operational hydraulic blocks to 6 water bailiffs and 4 extension agents in 1999 respectively. The manager and extension supervisor would then form an extra marching pair at a higher order hydraulic unit. These staffing levels are all consistent with the Agritex planning figure of one extension agent to an irrigated area of 70 ha or 50 to 100 farmers. It has been observed that African schemes are over-manned by international standards[10]. The consultant report also suggested that the Deure extension staff member to farmer ratio of 1:53 is excessive for a scheme with experienced irrigators (GKW/HTS/BCHOD, 1985, pp 33). Tiffen also observes a gap between scheme design and the quality of manpower available to do the job of management (Tiffen, pp 66,69 in Blackie 1984). At times the supervising DAEOs are not well versed with irrigation.

In government run surface schemes a foreman is usually in charge of the maintenance unit as observed at Deure and Chakowa. The foreman is usually a builder or can be a handy man. The main requirement is an ability to plan daily work activities, allocate tasks, control and be accountable for equipment. The tasks done by teams vary with schemes but generally they prioritise water delivery facilities like canals.

A comparative inventory of existing artefacts and their condition was carried out for the year 2000, against those in 1985, as summarised in table 4.3.1. At Deure as in Chakowa there are old tools and equipment including vehicles. Most vehicles and heavy equipment are obsolete and only serve to increase the volume and number of warehouse stock. There has never been an attempt to dispose of and acquire new and appropriate replacements. Most extension agents are not conversant with issues relating to fleet or equipment maintenance[11].

In Zimbabwe administrative support to smallholder irrigators has always been viewed as providing the necessary support to the extension services by way of housing, offices and regulations and procedures required for civil servants and their hired service providers to effectively discharge government duties at their out station. Provision of support to the local institutions has been neglected although the objective of capacity building has always been

[10] This is confirmed if one refers to staffing guidelines provided in Sagardoy *et al* 1982).

[11] In a restructuring seminar one principal at one of the local agricultural training colleges remarked that the locally trained agricultural engineers are good in irrigation but they cannot handle mechanics and power related issues. This was very much in line with the original objectives of forming a Department of Agriculture Engineering with a clear focus on mechanisation of smallholder production as per Minister of Land and Agriculture press statement of 8th August 2001.

included in almost all project formulations. At old government schemes like Deure most immovable infrastructure like houses, offices, storeroom and workshops belonged to the Ministry of Local Government and National Housing (MLGNH) who constructed and maintained the infrastructure. Derude and later Agritex paid rent for occupying these buildings. The current shift in ownership and maintenance of infrastructure now requires Ministries and departments to source funds directly for construction and maintenance from the Ministry of Finance, with MLGNH providing only technical advice and supervision to ensure that good workmanship and standards are maintained.

Agritex offices and extension workers' houses at Deure were electrified in 1991 after the river pump station was commissioned. Like most government irrigation schemes the office complex comprises an office for a clerk, two or three extension workers' offices, a general storeroom a mechanical workshop and storeroom. Generally the storerooms are full of obsolete material. These are spaces that could be used for farmer training and meetings instead of current open-air meetings.

The clerks at the schemes are primarily concerned with ensuring that: government procedures are followed; civil servants work properly; government revenue is collected and government assets are safe guarded even if they are old used items. Clerks are the government employees who form the core of the administrative support staff to the extension and other functional members at irrigation schemes. At higher levels they constitute the registry, human resources, stores, procurement and accounting sections. They therefore act as the repository of institutional capacity by means of records and assets and provide a collective memory for procedures and processes. Unfortunately they have no relationship whatsoever to the IMCs at irrigation schemes like Deure.

The Irrigation Management Committee (IMC)

Deure has two layers of local irrigation management: the block committees representing hydraulic units and a main committee established around 1981. The main committee is constituted as a "federation "of five block committees. Farmers in a hydraulic unit elect block committee members. As discussed in chapter 2 Agritex was instrumental in the implementation of the committee approaches and played a leading role in their formation. Each committee at Deure has a constitution and byelaws.

While IMCs and farmers decide and irrigate when they want, Agritex retains clear authority through the water bailiff and supervisor. There has been an attempt to schedule irrigation based on crop use of water but this was abandoned long before most of the local Agritex staff came to the scheme[12]. The consultant report of 1985 also acknowledged that: "*A system of scheduling irrigations strictly according to evaporation pan losses and correlated water use would be far beyond the capabilities of the local non-professional management. This is mainly due to variety of crops, such as early and late maize, cotton, groundnuts, etc each requiring planting dates and different irrigation frequencies. The best that can be achieved under the prevailing conditions is to recommend…. a two cycle system…*" (GKW/HTS/BCHOD 1985, pp 19-20).

The role played by traditional leadership in the identification of the Deure irrigation scheme is much more positively identified and acknowledged than in other schemes. The Chief was consulted in planning the in-field canal lining of Deure in 1991: "coincidentally" the first block to be lined was block C where members of the chieftainship are concentrated. The leadership is currently consulted and kept informed during maintenance events. The

[12] A soil physicist working at the Research and Specialist Services wrote a very detailed handbook on the use of the class "A" for scheduling. Unfortunately all examples pertained to commercial farming practices.

Chief was also involved in resolution of labour disputes. Traditional leaders are the final authority implementers of plot allocation in Deure.

Table 4.3.4 Duties and responsibilities of Irrigation Management Committees at Deure

Description	**1985**	**1999**
No. Operational Block Committees	7	5*
Terms of office (years)	2	2
Number of terms	Undefined	Undefined
Date last election held	1984/83	Most farmers could not remember
Bank accounts No.	Nil	Nil
Frequency of meetings	Monthly	Monthly
Across Block water distribution	Chairman & block committees & irrigation manager & water bailiffs	Chairman, Block IMCs, Water bailiffs and supervisor
Within blocks water distribution	Water bailiff if excess consults with block members	Water bailiff
Main Canal maintenance	Committee organises annual cleaning of main canal	IMC organises annual cleaning of main canal
Infield Canal maintenance	Derude	Block committee especially in "A"
Repairs-Fences and roads	Derude	Agritex
Source: Field observation and GKW/HTS/BCHOD 1985 *two blocks under rehabilitation		

When allocating plots at the new extension (old aerodrome) section, the Chief drew up a list by combining the council list and IMC list. The plots were allocated by drawing numbers from a hat, and prospective plotholders picked numbers that were verified on the ground by a field check, where Agritex staff confirmed the plot numbers and showed the plot boundaries. A few plots and plotholders remained unallocated. They were allowed to explain their need for priority. The chief listened attentively and after everybody had made interjections and comments he made the final allocations. Schemes like Deure that formerly involve traditional leadership in plot allocation also have byelaws that forbid plot renting. The Chief always threatens new plotholders with reallocation if they fail to utilise them.

The Chief is informed and gives his blessing to the across-block water distribution program that is adopted at the summer peak. The situation is similar for maintenance activities. The main role of Chief Chamutsa is in conflict resolution and disciplining farmers sent to him by the IMCs. The IMC refers cases to the Chief who adjudicates and if necessary imposes a suitable fine. The plaintiff is then referred back to the IMC to comply with the requirements of the byelaws and pay a fine or get a penalty as appropriate. This means that the Chief here actually works with farmers, Agritex and IMC and commands authority without being openly antagonistic for protracted periods to any institution as reported at Mutambara (Manzungu 1996, 1999).

The Ministry of Local Government and the Ministry of Water Development did not have direct contact with Deure farmers. They mainly worked through Agritex. The Ministry of Health also worked through Agritex: they used to employ snail rangers to monitor bilharzia risks, and apply molluscides. The molluscides found at Deure had not been used for a long time and nobody seemed aware of them.

This then is the structure of government actors and resources that, together with farmers, must provide the leverage to make the system stay operational.

4.4 OPERATION AND MAINTENANCE OF THE DEURE WEIR AND EARTH CONVEYANCE CANAL

The Deure weir was built on a rock bar extending across the river: it joins some rock bars on the right bank to approximately the middle of the river. The left bank where the Deure intake, and later the Bonde intake are located, had a lower rock bar and the concrete height is approximately 1.5 m. A 30cm concrete layer appears to have been added later. The structure originally had built-in desilting holes that were later plugged with concrete[13]. The weir structure still looks solid but there is evidence of a lot of honeycombing of concrete taking place on the downstream side.

The DWD operator-in charge of the Bonde pump station referred to the days when Agritex had a D6 bulldozer based at Deure up to 1997, used in desilting the weir, about twice a year. Farmers desilted manually between these times. The configuration of the new Bonde sump alongside has changed this situation. There have been several attempted modifications to date, the latest being the lining of the section leading to the Bonde sump. However, frequent desilting of the weir is still necessary to get water into the pumps. This has created disagreement and animosity between the Deure and Bonde irrigators (see chapter 7).

The Deure intake did not present any significant problems to the farmers before the Bonde pump station. It was desilted periodically with the supply canal[14]. Even siltation of the weir by cyclone Eline did not present significant drawbacks to the farmers. They worked together with their Bonde neighbours as two scheme-based groups and managed to clear the silt within a week.

The intake weir is not regulated directly at the river diversion site so there is no facility for closing the canal at the intake. A flush out with two control gates (sliding sluice gates) some 150m downstream is used to control entry of flow into the canal at times of high flood. The Deure earth canal runs a distance of 7 km from the weir to block A (Chinyamatikiti Block). The gates are in a rock section of the canal: the wholly in-cut canal was hand dug and has an embankment on the lower side only. The gates are also used to flush out this section of the canal. The senior water controller regulates the gates to allow the required flow into the canal, and ensures that the gates are closed off before any major rainfall events. There is no gauging device at the flood control gates and therefore the setting is done from experience. The senior water controller monitors water levels along the canal for a distance of 8km. The flume at the scheme intake is not formally recorded: recordings were initiated during this study but later discontinued, as in Chakowa.

The senior water controller is responsible for monitoring canal water flow and reports problems to the former extension supervisor[15]. He also advises on the intake water situation:

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[13]Some locals would frequently disrupt the water supply by opening the outlets to catch fish. There are still stones and sand bags being used to create temporary dams to trap fish and then catch them in the remaining water ponds.

[14] There was a permanent pool near the intake that was believed to be home to a mermaid "*njuzu*". A former Manager related stories to the effect that if the spirits were not happy then the "*njuzu*" (mermaid) could scare people away by splashing water "*kurova mvura*". It was also reported that some crocodiles manned the pool, and during weir desilting the farmers used tree branches to protect themselves. Now only one crocodile remains in a canal section just after the intake, the rest were driven away by the sand. The *njuzu* story is also no longer told – perhaps it was affected by the siltation also.

[15] There seemed to have been a temporary shift in 1999 of the person to whom "six boys" reported to under the team approach. He was temporarily required to report to the water management officer who was Mrs Nd. the former scheme officer and leader. The situation in year 2000 however seemed to be that the former extension supervisor was in control of the water bailiffs and the Senior Controller reported to him.

he used to monitor the canal by running along it every morning but now he cycles the canal everyday [16]. He is also a farmer in block A – Chinyamatikiti.

The Deure community comprising farmers, traditional leaders and local Agritex staff mobilise their labour and organise themselves in routine maintenance of their earth conveyance and lined distribution canal. Moving down the canal, farmers also flush out the inverted siphon[17] outlet built under a small stream some 1 km downstream of the intake. The opening of this outlet is a special event as it also presents an opportunity to catch fish. The siphon flush gate consists of a metal plate with four holes, which is bolted onto the concrete scour outlet. The structure was built in 1950 and the flushing kit that is the gate plate, bolts and nuts has never been replaced, although replacements are needed so that it becomes easier to open and close (although not so easy that it can be tampered with). Its distance from the scheme makes monitoring difficult.

The section between the weir and the inverted siphon is mainly deep, narrow and has rock for most of the section. It is also located below the DWD pump attendants' residence for Bonde. It does not present major cleaning problems because it is equipped with flush-out valves that are operated during most of the summer season. The rock also reduces growth of grass and trees. The section between the scouring siphon and the lined section that circuits a hill requires a fair amount of cleaning.

Farmers actions

When I witnessed farmers from one of the blocks cleaning this section in September 1998 I noticed that they were making the canal wider but shallower. On inquiry, one of the farmers explained that the water flow that can be discharged through a deeper and narrow section could be conveyed equally well in a wider but shallower section. They then acknowledged that in early days when the canal was maintained by DWD it used to be very deep i.e. "*wakanga wakadzama*". The DWD men used to clean it very often and it was always clean. In fact it was dangerous to cross even for cattle "*waityisa kuyambuka kana mombe chaidzo dzaisayambuka nepese pese*". The maintenance was then handed over to Agritex personnel.

Now with Agritex specifically responsible for desilting the canal, it has become necessary to mobilise the farmers. Extension staff and the IMC do this jointly. The desilting exercise is done between the 1st to the 10th of September. This period is timed to coincide with:

- The end of irrigation of wheat, which is one of the main crops in winter. The period has the least cropped area so there is least disruption to crops;
- The week before the early planting of the early maize crop. Cleaning of the canal marks the beginning of the summer maize and groundnuts planting;
- The beginning of the rainy season, to give the lowest water level to facilitate work at the weir intake;
- Just before the start of the third term so that school children can assist directly in canal cleaning or look after the younger children, so their elders especially the mother can take part in canal cleaning. Thus labour is more available.

[16] In fact the nickname "Six boys" was derived from his youth when he was a good boxer and soccer player. He is said to have demanded six opponents in either game.

[17] Inverted siphons are normally a designer's choice over flumes. The final decision is normally informed by extra costs of foundation and reinforcement requirements and more elaborate survey and design requirements of flumes.

All farmers should irrigate before the canal closure and the Senior Water Controller ensures that flow is closed off to meet this target.

Farmers, IMC and Agritex agree on a cleaning date and word is sent round. Farmers from each block are given a section to clean depending on its size. Under the old order i.e. 1998 and 1999 during the cleaning periods an EW, water bailiff and the specific block committee would supervise a specific canal reach. One EW would co-ordinate the whole desilting exercise by identifying areas of sediment concentration. He/she then planned and determined with the chairman and IMC the block canal reach allocations. The desilting operation involves the cleaning of the whole canal from the intake to the lined section. Members get up very early in the morning, around 3 o'clock, for canal cleaning. They start on the second or third days after water has been closed off, to allow the canal to dry off for cleaning. The water bailiffs do the measurements and the allocation of portions for cleaning to individual plot holders in each block. This ranges from 2 to 20m per household depending on the amount of desilting as well as on whether it is an earth or lined canal section. In some sections where substantial desilting is required as little as 1 m lengths are given.

Each farmer brings their own tools like hoes and shovels. Plotholders can be present in their own right or they can send representatives (who can be schoolchildren or employees or hired labour). The IMC members record the attendance register and use only the plot owners' names not the actual representatives. Block committee secretaries make records of daily attendance during cleaning or repair works. A block can be given more than one reach in different sections. They can be given a weir cleaning turn, a canal section on the main canal with a lot or fair amount of desilting and a section on the lined distribution canal. The IMC Chairman Mr M. explained that allocations on the main canal are sometimes made in order to allow the most upstream block A to be at the intake. The most downstream block or furthest i.e. block C is then given tasks nearest the field offtake as this gives everyone about uniform travel time. Realising the composition of cleaning teams which includes young boys, girls, old women and men, the farmers decided to opt for wider and shallower canal sections on the reach between the inverted siphon and the lined section going round the hill. No records were filed on past desilting, so no comparisons could be done with events in the research period.

At the section circuiting the hill, the farmers complained that there is always a lot of silt each year that needed to be cleaned. However, they however cannot "redesign the canal". The height of sand on the downstream embankment where they deposit the sediment has continued to increase. This canal section requires strong men to shovel out the sediment out of the earth to the lined canal interface. Agritex was requested to provide a bulldozer that could level off the accumulated sediment from the routine cleaning, but did not bring any equipment during the study period.

Dealing with a canal breach

Downstream of the lined section there is a section in which it goes through a box-culvert below a natural stream. The box-culvert is founded on solid rock and this implies that this canal section cannot be "redesigned by farmers." There is a relatively new settlement on the lower side of this canal section. This section of the canal breached one early morning in September 1998. It happened after the farmers had finished cleaning the canal and had debated with the researcher on the wisdom of the "redesigning to shallower and wider channel".

"Six boys" noticed that water was not getting to the Chinyamatikiti block. He immediately followed the canal and discovered the breach in its lower bank after a not so heavy rainy shower as shown in photo 4.4.1.

Photo 4.4.1 Main canal breach at Deure in1998

He immediately notified everybody, the extension staff and farmers. Everybody visited the site as shown. The canal is reported to have last breached sometime in the early 1990s during the days when the Agritex construction unit had just started lining block C canals. At that time, the then construction unit supervisor - also a former Deure manager - commandeered the unit with its equipment to spearhead the repair work. Earth was hauled from borrow pits, and casuals and some farmers helped in compacting the embankment back into place. The whole operation was completed in less than a week.

There were different explanations for this canal breach. The chairman of the IMC Mr M and the senior Agritex officer thought that an isolated farmer who had settled just below that section of the canal caused the breach. In their view a footpath leading to the canal used for fetching domestic water had formed a gully during the rains, allowing water to flow over the embankment. This overflow caused further erosion and weakening of the embankment leading to its failure and canal breach.[18]

What was never considered at this stage was the effect of "re-designing by desilting" on the canal. The possible effect of the box culvert, which was not redesigned and its effect on the redesigned upstream section was not considered, at least at this stage. Farmers wanted a quick practical solution.

The farmer leaders realised that their crop was in danger immediately and on the same day as the breach requested Agritex for ideas and assistance. The officer had virtually no heavy equipment on site. The option to reconstruct the embankment and patch up the gully formed by the breach was ruled out as impractical. They then agreed to realign the canal, and by going some 10m back they would cut another canal section and link it with the older canal a distance of 80m downstream. Agritex was asked to immediately do the layout design and plan realignment with canal dimensions and required depth of cut. The officer had no equipment for surveying and had to send one EW to borrow this from Tawona a neighbouring irrigation scheme. The farmers suggested that they immediately start digging next day on a route to be given by Agritex from experience. Agritex would do their final alignment and levelling over the weekend. On Monday farmers would resume digging and complete by Wednesday so as not to stress their crops.

[18] As a consequence of the breach, the settler – a traditional healer - lost a hut used by her son (fortunately away) and had her flock of chickens washed away. She appealed for sympathy from the "canal owners" and users but most did not sympathise.

Farmers met the next day - a Friday - after the breach, and blocks were allocated sections with the normal arrangement of supervision and recording. The farmers immediately started digging as per the Agritex route to be confirmed later. Agritex staff spent the whole day Saturday surveying.

Photo 4.4.2 Farmers realigning canal after breach at Deure

The officer, all EWs and all water bailiffs and other Agritex staff were on site. They put in pegs of the final canal bed level. A maximum cut of over 2 m was to be dug. This section would be narrower than the other canal sections to avoid excess digging work. Besides this was an emergency to save the crop from failure.

Early in the following week farmers had completed the digging of the realigned canal section. They then engaged in a massive desilting programme. They desilted the canal section downstream of the canal breach to the original bed level. Some said the desilting had been done to an extent never done before. Plotholders were allocated 1m length of canal reach in their respective blocks one would see young and old women, young men and old men, the talkative and the quiet each trying to complete their day's allocation as shown in photo 4.4.3. Block secretaries had to be among the earliest to arrive so as to start recording, although they remain seated throughout the exercise, and were the last to leave after each member of the block had completed. Final levels were pegged in at intervals by a team led the EW with the longest work duration in the scheme.

The cleaning exercise was taken beyond the box culvert as far as the lined portion. Portions where the water was now overtopping bridges were desilted, as were division boxes. All the sediment was put on the lower bank of the canal. There was very little spreading of the sediment to prevent it from falling back. A few farmers who could not haul out the sediment with shovels dug it using hoes and threw it out using their bare hands.

However, two problems were immediately noticed which required immediate attention. By digging out the sediment it became very clear that some of the old overchutes needed to be rehabilitated. The paths of sand moving into the canal became very clear - often linked to waterways, cattle paths and roads - and some suggestions were discussed regarding the need to train water over the overchutes. Some farmers suggested building some wing walls to train the water over the chutes as had been attempted by maintenance gangs earlier on.

Photo 4.4.3 Desilting conveyance canal after canal breach at Deure

The second issue was the need to have a buffer zone fenced off on either side of the canal in order to restrain people and cattle from getting into the canal, and even being washed away by the deeper canal. A proposal was made to approach Agritex to supply fencing material for this buffer zone, 10 m downstream and 20 to 30 m above the canal line. A strong sentiment against people living upstream of the canal was made, but no one was in a position to influence authorities against them[19]. Suggestions were made for digging of conservation works, which the new settlers could dig. However not much support was gathered over this proposal[20]. The desilting exercise continued including the lined canal. Even the section of the flume just upstream of the block A Chinyamatikiti was cleaned so well that one could now see the raised section of the flume throat. Unfortunately despite all efforts the DWD would not replace the gauge plate.

Changing system environment and its effect on siltation

The cleaning exercise at Deure did not go back to the portion upstream of the lining going round a hill, and therefore that redesigned section retained its new wider and shallow re-dimensioning. The operation of this canal had definitely been affected by both changes in the system and in maintenance practices. The farmers probably are contributing more to the problem by having a piecemeal approach to the problem, although this may be their practical response to maintaining a structure whose design did not anticipate maintenance by women and children. The current canal siltation level exceeds the design parameters of the canal: in the original design the canal passed through natural forest area with no settlements, no cattle, no cultivation. It could take in all the runoff that was not laden with sediment. This is evidenced by the lack of storm drains and the small number of overchutes. However the environment has changed over time. This alone could be the reason for redesign, including to revisit the adequacy of the drainage facilities to match with the higher sediment load resulting from increased settlement. The Deure and Chakowa supply canals offer opportunities of upgrading the canal system to cater for increased environmental load, with lining or enlarging overchutes and modernising through piping.

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[20]Construction of contours is an area that was highly sensitised during the days of the liberation struggle, and still remains a controversial issue. While many options like the highly publicized vertiver grass have been tried, it still seems none is as effective as contours. Therefore in situations like the Deure canal siltation other solutions remain elusive. However desilting to the original levels did generate debate on preventative options.

Yet another reason is the change in the type of labour[21] providing the actual maintenance. When promoting change from government to farmer management nobody considered the nature of operation and maintenance responsibilities, the composition of the government contribution, or style or complement of management in relation to the farmer. Without this type of analysis one cannot immediately find what design is appropriate for the new management regime as in the case of deep narrow canals. Delivery problems may not be a question of not maintaining, but rather not maintaining to the design requirements, given changes in the wider environment. Any upgrading and modernisation should therefore not be simply a question of fashion but a real option that incorporates the operation and maintenance requirements of a system and its changing environment.

4.5 BLOCK ROTATION AT DEURE: PROPORTIONALITY AND EQUITY

At Deure most blocks have multiple offtakes from the main canal except for block A and Block D1 that have single outlets see figure 4.5.1. Most of these outlets are gated and do not have cross regulators in this main canal. The water bailiffs are acutely aware that this allows all blocks to share the deficit in the water supply. During low flow all blocks will get a low allocation. Farmers in block A do not interfere with the canal water level at their outlet. Sedimentation occurs just after the cut-throat flume where the channel widens. The road crossing[22] which also doubles up as an overchute just downstream of the flume and outlet gate holds back flow and facilitates the deposition process

Block D1 outlet has cross regulation on the main canal although there is a groove provided which allows for use of stop logs or a gate to regulate or divert flow. The block D1 outlet gate is set and locked by the same water bailiff that operates block A outlet gate. The water bailiff first ascertains the number of farmers requiring water.

He then uses his experience to determine the required reading on the Parshall flume some five metres (5m) downstream of the outlet to gauge the required discharge. The sluice gate is adjusted to a certain number of holes and locked in that position. While he used the gauge reading on the flume, he did not have the discharge-rating curve for the structure. At the offices nobody seemed to be aware of such information. The explanation given was that most of them were new and required training.

Block C has nine outlets taking off from the supply-distribution canal. It consists of three small blocks less than 5 ha each and a larger block of 30 ha with a total of four outlets. All offtakes serving this block are narrow (0 to 15 cm wide) with metal sluice gates and a handle with some having a facility for a lock. The block has one water bailiff, a farmer in this block who lives near the supply canal line. He was also the secretary during the water management meetings held every Wednesday between the Agritex Supervisor, the EW responsible for water management, the water controller and the water bailiffs.

[21] Rukuni analysed the labour available at the neighbouring Nyanyadzi smallholder scheme and found that in an average family of 11, two members work outside the scheme area and 5 to 6 members are below the age of 15. This means that the most of the available labour is young (Rukuni, pp 405-406 in Blackie 1984). Young children, women and old men mainly carried out the maintenance works in reality while the canals were designed with a view of maintenance being provided by men formally employed by government institutions.

[22] This bridge and overchute structure is also a maintenance problem as water head created leads to hydrostatic pressures that punch through the bridge floor and lead to water flowing down the road. Almost every year the local Agritex builder routinely repairs the structure by either plastering or putting a layer of concrete on the road crossing to stop the “spring” flows. After the canal was thoroughly cleaned, the water level at this road-overchute no longer posed problems.

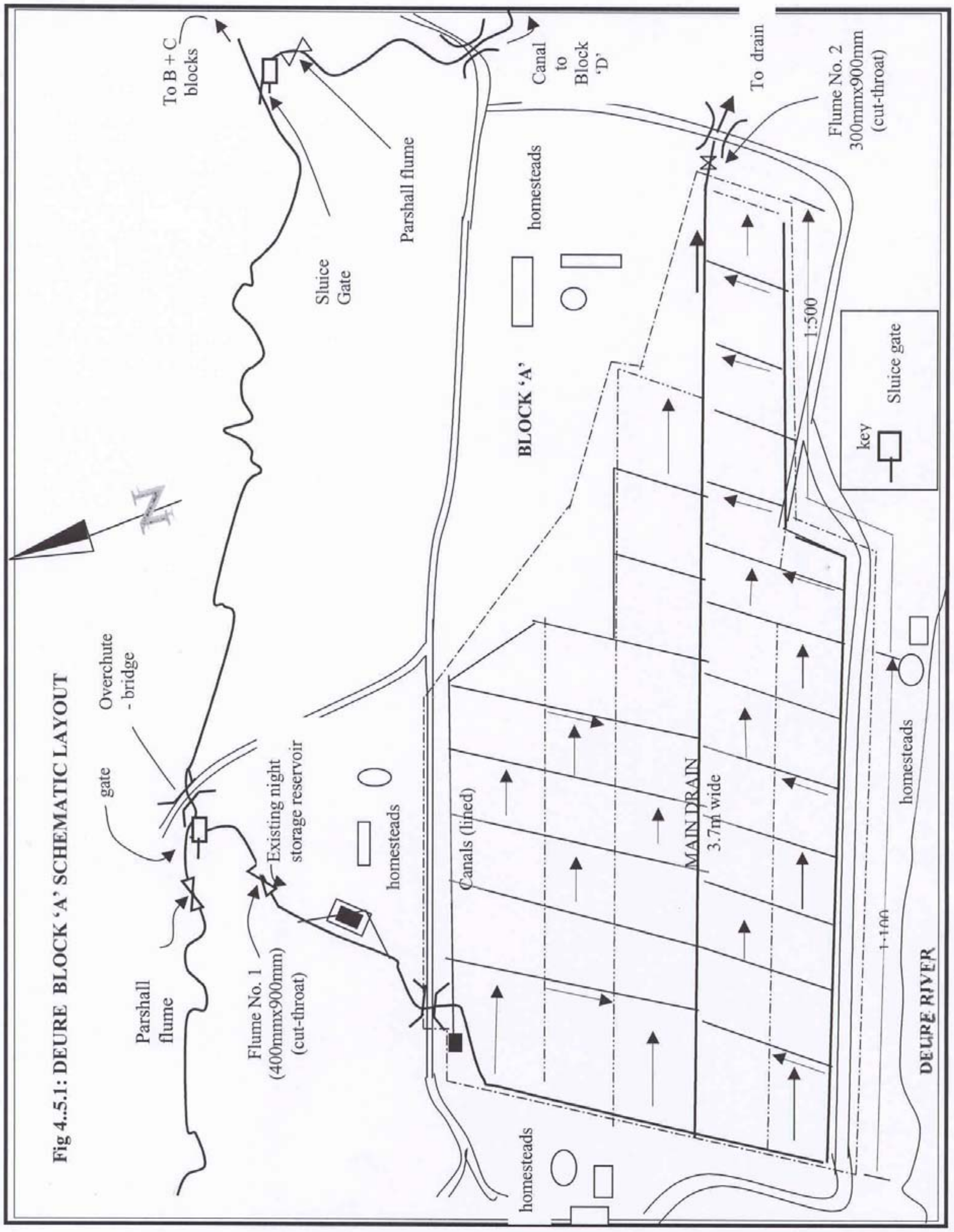

Fig 4..5.1: DEURE BLOCK 'A' SCHEMATIC LAYOUT

These meetings weathered the changes in the institutional structure brought about by teamwork approaches[23]. The water bailiff for block C sets the gate levels for each outlet everyday in the morning and resets them again in the afternoon. He also sets the water level for the evening for farmers who want to use the water at night. The night allocations are reflected in this block C's water bailiff water allocation records.

The block between the former airstrip and the supply canal is considered to be part of block C. However in this study it was considered as part of block B. At Deure block B is the largest and covers about 170ha which is about half the scheme area[24]. It comprises three major outlets each having movable gates and a weir water level control that also doubles up as an internal spillway. The first major offtake from the main canal after the road crossing supplies water to B1 block. Block B1 has one distributary canal from which a long weir and standard gate assembly supply water to four or five gently sloping canals (gradient 1 in 1000 to 1 in 2000) about 1 km length each.

The canal section that conveys water across blocks is lined for about 8km from the off-take to block D1 up to the last off-take in block B giving a hierarchical canal system. It is characterised by a large number of off-takes on secondary canals and even on the distribution canal, as well as the long (8 km) distance between head and tail end which gave inequity problems (Horst 1998 pp17). Operation and maintenance of this canal was giving problems before lining. It was therefore decided to line this section ahead of lining infield canals and the supply canal. The cross block distribution canal flows continuously during day and night. The water bailiffs for each block indent into this flow by taking out flow required by their users. They each gauge using holes on the outlet gates. Excess water at any time is discharged into the Save River by outlets suitably positioned. The same outlets are also used to discharge flow to facilitate maintenance like canal repairs or cleaning as well as emergency lowering of canal flow levels[25]. The first outlet is between block A and Block D1 off-takes. The second one is in block B11 and the last in B111.

The bifurcation splitting flow between block B1 and blocks B11 and B111 has no cross regulation. Each morning the water bailiffs spent time adjusting these gates to ensure that their blocks get what they need. The water bailiff for block B1 tends to secure sufficient water for his farmers most of the time and they rarely irrigate at night. The partitioning of water to blocks is very much related to the maintenance. During the year the water bailiffs do the minor maintenance of their block canal reaches. This involves walking the canal section and removing trees and other debris. As the demand for water increases the operation of each outlet on the distribution canal attracts increasing attention from other water bailiffs, farmer committee members and finally farmers. Initially water bailiffs are seen partitioning water between outlets with increasing consultation. They end up doing this together especially for the tail end outlets of the blocks B1, B11 and B111. Committee members sometimes join them in the mornings or afternoons when they set the gates to be sure that nobody loses out. Locks are used to ensure that nobody resets the gates besides the water bailiff. When there is too much sediment in the canal during the cropping season the farmers and water bailiffs set dates for cleaning the canal or structures notably the culvert before the B1 outlet. They normally use the drainage outlet between block A and D1 to divert flow into the Deure River.

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[23]I witnessed the organisation of these meetings under the new "teams and specialisation" order. There is very little change. The team simply allocated the water management role to one member. This role was given to the lady extension officer. She handled the meetings for a while. There was a reshuffle and specialisations were superimposed with blocks and the old order restored.

[24] Part of this block (about half) was being rehabilitated during the study period.

[25] According to the water controller "Sixboys" the outlets are used almost every summer for emergency lowering of canal levels. They are also opened during any canal cleaning sessions as a way of hastening the canal drying as well as flushing out sediment.

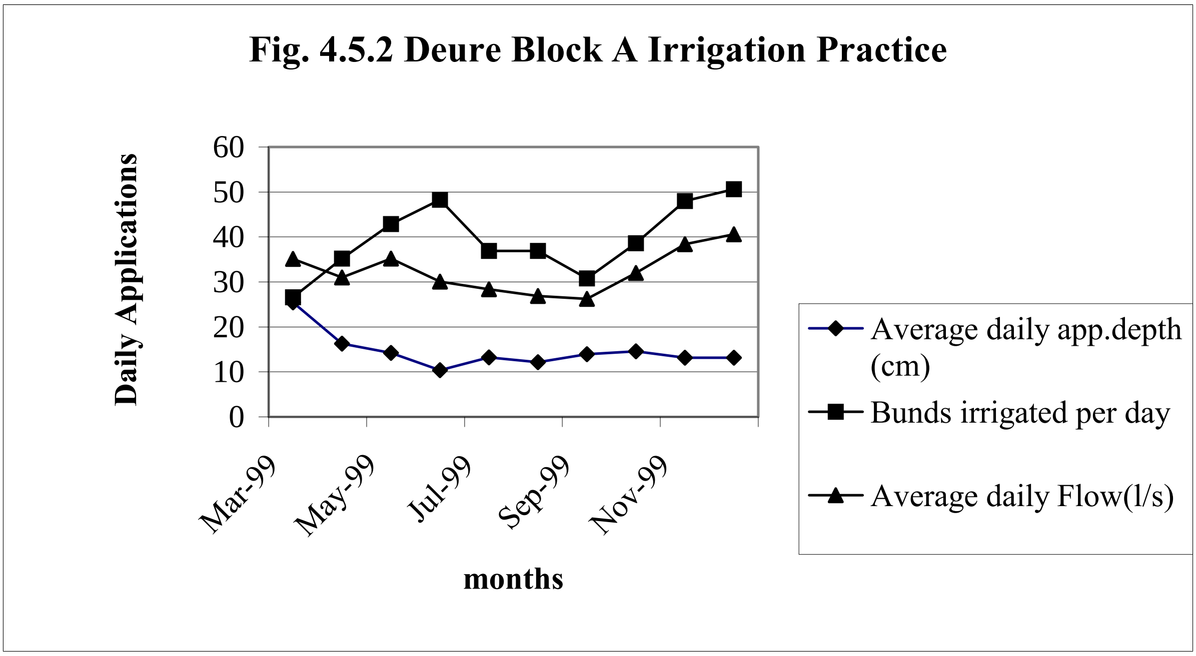
By doing this they avoid interfering with the supply canal and thus ensure an early resumption of supply after minor repair and cleaning works. Normally all farmers are called upon to clean the distribution canal. During this cleaning the block A farmers who are upstream are requested to attend to the main canal or do some minor desilting of the Deure river intake.

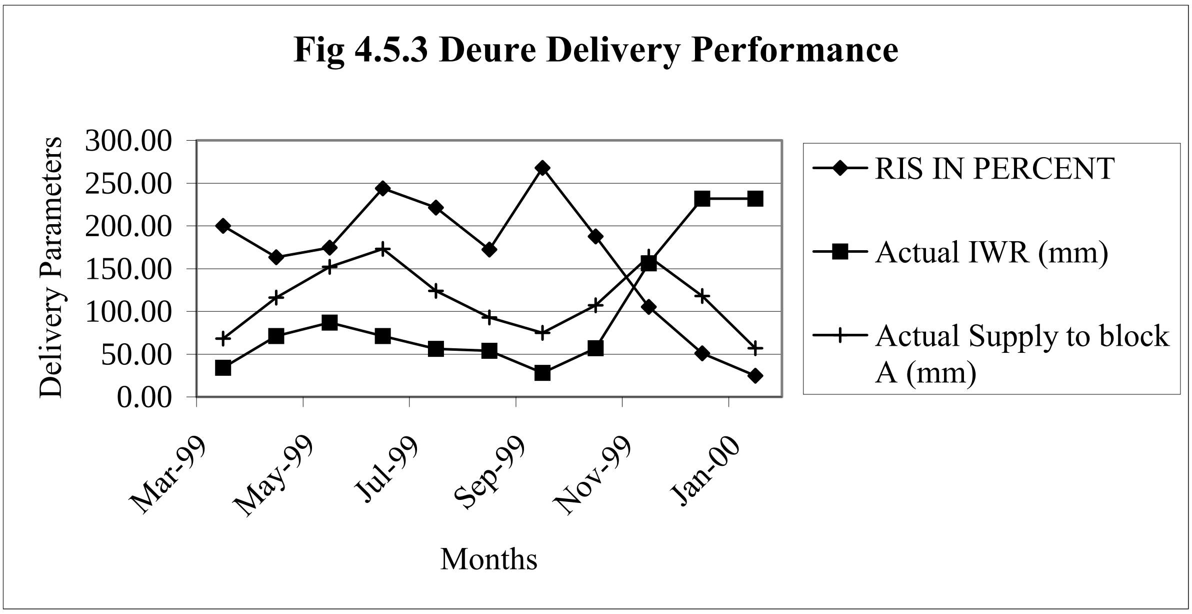
Deure at peak demand-arranged and deficit irrigation

When demand reaches a peak - this normally occurs in the period November to December and in some years January - the water distribution arrangements cease to be a water bailiff and IMC issue. Both extension staff members and general farmers become involved. A meeting is held and a schedule is worked out which establishes sharing arrangements of water across blocks by rotations. Pairs of blocks that is A and D, C and B1 and B11 and B111 receive all flow typically for two days and then remain dry for the next four days. During this time only the specific blocks have full access to both daytime and night flow. Fines are stipulated for breaching regulations and these normally include withdrawal of irrigation turns and some payments. The practice as observed over the research period works well. Even those farmers in block C that has multiple outlets and the traditional leadership tend to abide by the rule. The traditional leader and councillor are involved in the process of setting the rules and enforcement. The two aspects that seem to account for success of the scarcity management is the continuous 24-hour flow in a 12-hour irrigation scheme, and the lined, uniform section distribution canal section from block D1 outlet to the intake to B111 at the tail-end. This contrasts with the Chakowa and Musikavanhu cases. The Deure distribution canal is not structured and involves active management of flow (Shanan 1995; Albinson 1996; Pradhan 1996). This is made possible by the strong institutional arrangements together with relevant technology.

The fact that a 24-hour flow is available when the scheme normally operates only during the day essentially gives the scheme farmers time for catching up, especially by block C farmers. During peak demand this night flow is theoretically and practically available to irrigating blocks. Deure farmers do use it to save their crop. Besides irrigating far into the night some are up very early around 0300 hours in the morning. Farmers report that the cool night temperatures make night irrigation “comfortable”. The former councillor is understood to have influenced the Buhera council to install a tower light in the old business centre instead of at the new growth point. The light is appropriate for night irrigation in block C and B at the “tail-end”. These are some of the decisions that the local representatives make based on their acute understanding of the local conditions which outsiders never understand (Moore 1990). The design feature that enables the community to have a functional strategy is the uniform canal capacity for the distributary. This enables the whole flow to be diverted to downstream blocks. This effectively means the downstream users can access as much flow as those upstream under a suitable institutional arrangement.

The practice of arranged irrigation across all blocks at Deure leads to deficit irrigation in the peak demand summer months. As discussed in section 4.2 planting of the summer crop takes place immediately after cleaning of the main supply canal by all farmers in all blocks. The whole scheme plants the staple maize crop at the middle of September as shown in Tables 4.2.1 and 4.2.2. Any minor staggering of the crop that occurs is due to individual farmers’ inability to mobilise resources like ploughing and seed. Although a consultant in 1985 tried to design out the deficit in December resulting from farmers’ planting practice, to shift maize planting back to from mid/late October to late/early November, farmers kept the September planting date.





The final cropping gives rise to what Horst calls a mono-crop stand in all tertiary units: in such a situation a fixed flow throughout the season results in unacceptable additional operational requirements (AOR)(Horst 1998, pp102). The two options suggested to manage flow are to increase the supply to each tertiary unit as the crop demand rises, which is what the water bailiffs do with increasing farmer participation. When it is no longer possible to increase the flow, the farmers and water bailiffs then meet and agree on block rotations. These block rotations are what Horst refers to as "pulsed" irrigation whereby supply to a tertiary unit is either zero or full. These result in low to medium AOR (Horst 1998, pp103).

In reality the practice at Deure leads to deficit irrigation as the RIS falls below 100 percent or less than unity) as from November and continues to decline with the season as shown in Fig 4.5.2. The flow increases marginally in December probably due to reduced losses. All farmers are eager to utilise available flow and the canal is operated at its peak capacity. The number of bunds or total area irrigated each day increases substantially as shown in figure 4.5.1. This results in reduced depth per application down to 120 mm[26] per day as shown in figure 4.5.1, when the irrigation water requirements are as high as 230 mm per month as shown in figure 4.5.2[27]. The deficit is visible in the field, as most crops will be showing signs of stress in the hot sun. This is the time farmers are reported to fight over night irrigation turns. This confirms the finding by Makurira (1991), who carried out detailed advance–recession, infiltration and moisture extraction study in 1991 in block C for maize planted in early September and found moisture deficits throughout the soil depths consistent with under irrigation. He recommended that fewer siphons and more infiltration time be adopted. The findings in this report suggest that while Makurira's study observations were correct, the recommendations cannot be adopted as the under-irrigation is due to a deliberate practice adopted by the farmers. This shows how the interpretation of data can be misleading without thorough understanding of the irrigation system practice. The pattern of low relative supply is consistent with Makadho's findings of relative water supply (RWS) in gravity surface schemes (Makadho in Rukuni et al, pp59).

Mukururira showed how farmers typically use around 8 siphons per bunds with low borders with a discharge of 15 l/s for 14-20 minutes. This supplies less water to the all crops in quantitative terms, but this application is more frequent and adequate in timeliness terms. The net result is that the crop yield is mainly reduced due to effects on grain filling and not due to poor pollination. The perpetuation of the practice at Deure with cooperation from all farmers suggests that the yield reductions or can be "lived with" using a term from Vijfhuizen (1998). This "pulsed irrigation" situation contrasts with the Chakowa "winner-take-all" case where tail-end farmers opt not to plant until the rain come leading to two different cropping patterns for head-enders and tail-enders.

Thus the cropping pattern for Deure is closely linked with the water management regime. The tight water schedules and low irrigation depth have given rise to a culture of night irrigation at Deure, particularly in block C and B. Some farmers say that the tower lights that were erected at the shopping centres have increased the incidence of night irrigation in these blocks. This confirms that the farmers are aware of the yield reductions and have adopted secondary cooping strategies to reduce the stress effects of the "equitably" shared deficits.

Farmers' water application practices at Deure

The field application uniformity at Deure is high due to the second stage formal levelling that took place during the lining process from 1991 to 2001. Advance and recession measurements gave uniformity in block C in the range of 80 percent (Makurira 1991). The fields had initially been levelled at the start of irrigation in the 1930s. Farmers continued levelling and during the rehabilitation and lining designers made minimum changes to the layout of the bunds and also took note of the farmers levelling concerns[28]. This is evidenced by the lack of

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[26] In this study the average depth of water applied at Deure as shown in figure 4.5.1 was determined from measurements of flow into an irrigation block and dividing by the total number of bunds irrigated over a growing season.

[27] Makadho uses 0.8 RWS as the seasonal critical adequacy level from which he determines the reliability index based on the number of decades exceeding this figure. He fails to take into account the farmers deliberate practices in deficit management.

[28] Block A and block DI were lined and levelled in the 1970s reported under Sparrow. They are quite satisfactory according to the farmers and this actually inspired me. I was involved in the rehabilitation and lining of block C and B from 1991 to 1995.Experience with use partial levelling and use of other less precise calculation methods at Nyamaropa from 1987 to 1990 had shown me that piece meal approaches in levelling are the worst thing that can happen to farmers at a surface irrigation scheme.

ties in the fields. Typically during irrigation young children siphon and control the water while adults are keeping an eye and weeding in adjacent bunds. One lady in Block B explained that the fields are now so well levelled "*wagadzana*", to the extent that one simply needs to siphon and the water will move and distribute on its own without guidance.

At Deure farmers prefer to protect their fields against erosion by use of maize, wheat and groundnut stover or plastic bags at the point of discharge contact rather than use less siphons because they want to get through the irrigation as fast as possible. This is in contrast to Chakowa head-end farmers who prefer irrigating for long time periods. Farmers use 40 to 50 mm diameter PVC siphons that are mainly individually owned at Deure.

Water bailiffs monitor irrigation turns. At Deure water bailiffs determine the irrigation turns under normal supply. The water bailiffs keep a pocket record book and record farmers and their turns. According to the water bailiff Nduna this record book is the final answer to all arguments "*ndiko kan'anga kacho kanopeza bopoto*". Farmers respect the bailiffs and normally their word aided by the record book is final. In fact farmers at Deure believe that the government-employed water bailiffs are indispensable "*Hatingazvi kwanise zvekupana mvura tega kana vasipo rigesheni ingatofa*".

Deure field canal, road and drain maintenance practice

The water bailiffs and farmers maintain block level irrigation infrastructure. Maintenance of lined canals was the preserve of block A and block D1 until the lining of block C and B blocks in the 1990s. The block A and D1 canals were well maintained. Block A has a very simple closed network of canals with a central drain and a canal forming a horseshoe. Tertiary canals take water to the centre. Maintenance mainly involves cleaning canals of sand and vegetation matter. Farmers here clean their own canal sections, and are so proud of their irrigation infrastructure that they clean roads, canal offtakes and drains. The feature of farmers undertaking routine cleaning of drains is special only to this section Block A-Chinyamatikiti of the scheme. In Zimbabwe, I know of no other scheme where farmers make a deliberate attempt to clean drains, which farmers say has happened since the scheme started. Each irrigator cleans his/her drain, road and canal reach. In addition they had pegged out portions of main central drain, and farmers on either side also clean the drain up to the centre line of the drain. The water in the drains is moving most of the time and no signs of salinity are visible. Farmers near the secondary canals are exempt from drain cleaning but they look after the canal and road reach.

The same situation was observed in block D1: although the drains are not as well positioned, the duties are also clearly laid out. The cleaning of drains is not as thorough but it is quite satisfactory. The newly lined blocks of C and B have farmers who were used to working with earth channels, so the drains did not really mean much to them. When the scheme was lined and a clear distinction created between drains and canals, these farmers have been found wanting. In the main block C and the Block B the canals, roads and drains are well looked after. However the secondary drains from C and B that combine to form the main outlet are neglected. The same applies to drains coming out of block B11. Some have been used as supplies to thriving homestead schemes. The drains have occasionally flooded roads making them unusable for a day or two in block B111. The main drain is overgrown to a reed locally called *mabungwe* that grows fast and is associated with saline and waterlogged conditions that is particularly difficult to control if kept watered. The net result is a visible layer of salinity encroaching on fields in block C downstream of the main road and at the homesteads. A cholera outbreak occurred in 1998 and affected some homesteads near the main drain downstream of block C. The area has a high water table due to the drain and homestead irrigation. There has been no attempt to institutionalise drain cleaning. The same applies to care of the common roads. The current resident engineer has been persuaded by the farmers and extension staff to prioritise the lining of the drain and repair of the road over of the lining of the supply canal prioritised by the central head office planners. The issue was still in debate in mid-2002.

4.6 DISCUSSION AND CONCLUSIONS

The Deure scheme was built and first maintained by government agents, but with a gradual lowering of the government contribution to the operation and maintenance as well as authority. Unlike Chakowa, the Deure community has responded by gradually appropriating some management responsibilities and artefacts. Helped by the simple weir-gravity-canal-surface technology, flexible main canal and improved reliability of supply, the positive attitude of the community results in a sustained reliable delivery of flow to the scheme even in times of canal breaches and infrequent cyclone visits.

There is therefore a genuine possibility of establishing practical equity at Deure. The downstream blocks being bigger (about half the area) have the institutional muscle in terms of human numbers to persuade and or force the small upstream blocks to comply. The positioning of the traditional leadership in the middle block makes this the pivotal position. The peak water demand occurs in November to December when the main livelihood crop maize is being irrigated. The conveyance canal has capacity to send all flow to downstream blocks as required providing flexibility that improves cross block equity and fosters cooperation. The farmers can vary discharges as required using gates and are thus able to manage varying flow regimes. The absence of pumps to maintain and power costs to worry about is an added bonus that only helps to cement the institutions and give the simplicity that characterises and promotes FMIS.

While the four major management service areas still face limitations, the agronomic advisory services, water delivery operational support, infrastructure maintenance support and administrative assistance are still present and liase together. There is clarity of maintenance responsibilities at Deure as observed in most old schemes, in the water mobilisation (diversion or abstraction) and in the application subsystems. In this the Deure farmers simply used "*whatever useful forms of traditional co-operative village structures are in existence"* (Makadho, pp 211 in Blackie *opcit*). Farmers used family equipment, and organised themselves and prepared their own attendance records, registers and financial transactions. The area with most confusion and weak structures is the across - and in - block maintenance where most of the responsibilities are expected to be done by IMCs. Some leverage exists that may support government attempts to handover responsibility of maintenance of management support subsystem infrastructure at Deure. The technology at Deure is simple gravity using traditional canals and standard Agritex gates. This coupled with reliability and security offered by the Ruti Dam has made it possible for farmers to have sustainable participation in water management. This simplicity seems to be providing the bulk of the leverage of the MSSS at Deure. The performance study goes to show that under these simple technologies and operational rules the farmers perception of performance varies. Initially farmers expect the system to deliver adequate water to individual farmers. When they find the system constrained they increasingly participate in the water distribution process with the object of ensuring equitable deliveries. They end up changing the continuous supply to blocks to block rotations thereby converting into "pulsed irrigation". The farmers realise that they are in deficit and try to further increase water supply by engaging in night irrigation at the critical times.

However, monitoring and enforcing maintenance of repairs still presents problems because while maintenance is actually a cost to farmers the effects of not maintaining are not felt directly by the individual farmer. There are no guidelines to show farmers the limiting levels of canal siltation at which the system performance becomes adverse to individual application, group water distribution or scheme water delivery. There are few activity and work records, work registers and evaluation to help as benchmarks for future improvements. This makes it impossible to use the documented experience at the scheme to improve performance from an institutional and technological viewpoint.

A trial has been set up by the ZITC with Israeli support to compare the practical benefits of surface, sprinkler and drip systems at Deure under smallholder irrigation. This is meant to help in the decision to either convert the Deure water mobilisation to a gravity pipeline delivery branching out of the proposed Bonde canal (see chapter 6) or to line the canal as proposed (GKW/HTS/BCHOD 1985). Theoretically piping water to the scheme from Bonde or lining will both reduce the maintenance requirements for the farmers. The issue is to determine the additional benefits that will accrue to the scheme to fully justify either intervention. The second option is the installation of drainage works to control the water table as additional components of the farmers' irrigation system.

The Deure irrigation scheme presents a case of a scheme where the community and government have worked together to progressively improve a water delivery service. The development of Deure market has dictated changes in cropping programs that have put pressure on farmers to concentrate planning of the early summer crops. They have responded by appropriating the annual maintenance of the weir and conveyance canal. The short cropping season created a sharp peak crop demand. The local community has adapted to this by adopting a deficit irrigation block using the flexibility of the system to supply two hydraulic units of water at time. Nevertheless, the scheme has block level problems like night irrigation, snails in canals, drainage and poor management support infrastructure maintenance, although these do not have significant affects on the livelihoods of the farmers.

The key points that enable leverage at Deure are the simple rock founded weir, gravity canal conveyance, flexible gated distribution canal that are supplied a secure stabilized water delivery that a is managed by cooperating government and farmer institutions to grow livelihood crops and commercial crops. The supporting institutions work in harmony to appropriate and cover up any shortfalls in the WDSS. Gradually farmers have appropriated canal maintenance to meet the maize planting dates. They then participate and make water allocation decisions resulting in the use of "pulse" deficit irrigation to coop with a high peak maize requirement. Government authority in everyday water allocation is respected and supported by local institutions.

Farmers and the supporting government institutions at Deure still have to identify possible improvement areas and strategies taking into account required contributions from both the water delivery subsystem and the management support subsystem. The current focus on only adopting "modern" water control hardware only - as will be discussed in chapters 5 to 8 seems to be a failure to identify the leverage that farmers can give to existing technology (Senge 1981).

5 MUTEMA: A PUMPED CONVENTIONAL OVERHEAD SYSTEM UNDER STRESS

5.1 INTRODUCTION

The Mutema scheme was started in the mid 1930s, with water diverted from the Tanganda River by gravity for surface irrigation of 150ha. The scheme was later extended to 262ha with the addition of 90ha of sandy soils in 1962, when the first borehole was also developed to supplement water to the surface irrigated fields. More boreholes were drilled and equipped in 1973, when it was decided to convert 182ha out of the total 262ha to a conventional lateral move sprinkler irrigation system. This left an area of 80ha under the original gravity surface irrigation arrangements with water supply still coming from the Tanganda River.

A former irrigation manager explained that "flexibility" was designed in to facilitate salinity management given high levels of salinity in some borewells. The borehole pumping units were directly managed by DWD in both operation and maintenance. Various government institutions managed the distribution and application system over the years. The common factor was that an irrigation manager and later an Agritex extension supervisor was responsible for a public repair workshop, had a team of water bailiffs who controlled lateral changing by farmers, and led a team of extension agents. Farmers paid maintenance charges or fees to the manager's administration staff as in other schemes, and still pay this to Agritex (now AREX) administrators. An Irrigation Management Committee (IMC) of some form has been present for over 20 years, working alongside the DWD and Agritex staff.

Mutema farmers initially grew crops that were controlled by government but later turned to higher value crops dominated by cotton and beans. Cotton has increasingly dominated the summer cropping program at Mutema, mainly due to unreliable water delivery as well as poor access to "niche" markets. Recently, the scheme has dropped winter beans production, due to low yields attributed to growing salinity. Now tomatoes are grown for the canning industry in Mutare as the main winter crop. Unreliable and inadequate water at Mutema is mainly attributed to frequent breakdown of the pumping plant. However, in 1991/92, when there was a significant drought, and the boreholes at Mutema were operating well, the Manicaland province invited President Mugabe to visit the Mutema scheme as part of his meet the people campaign. Dr Makadho, the former Director of Agritex, called this the “oasis effect of irrigation” in this case it was “resilience of borehole technologies in a drought year”. When most surface water schemes were struggling to get water, the Mutema farmers had a beautiful tomato crop. A Government official interviewed during this study admitted that the performance of the scheme during the 1991/92 drought influenced the choice of borewell technology for Musikavanhu.

Mutema presents second-generation technology that was designed to work under a defined system environment with respect to operation and maintenance[1]. The Mutema scheme is also unique and interesting because it combined the first set of modernisation technologies

[1] I call this second generation technology simply to distinguish the pumped overhead system from the original unregulated run-of-river gravity surface systems that are consistent with Alvord's designs for Chakowa and Deure. Manzungu (1999, pp 41) reports that Alvord was instrumental in the original design of Mutema in the period 1931 to 1947, although scheme members did not mention him by name as in Chakowa and Deure.

in a relatively large smallholder scheme in 1970[2]. It is a groundwater pumped overhead irrigation scheme. Its history therefore also represents a thirty-year technological trajectory of the operation and maintenance of a "modern system" in Zimbabwe. Here, however, the management sub-system has had little success in leveraging adequate and reliable water supply, and very little serious thought has yet been given to an appropriate management system for pumped overhead irrigation technology. This chapter examines the main features of the scheme and changes in its WDSS and MSSS, with performance analysis of the one borewell still operating, and of sprinklers in plots of block A, as well as questions and observations related to O &M on the scheme. The impact of the O&M on water delivery performance is shown by the RIS variation over time. The chapter then concludes that the local management cannot provide the required leverage to sustain sophisticated technology given the low returns from their cropping systems.

5.2 CRITICAL FEATURES OF WATER SUPPLY AND PRODUCTION

Critical features of the water supply

The Mutema irrigation scheme has three blocks: block I, the northern sandy sprinkler block; sprinkler block II near the Agritex offices which is more clayey and in the south; and block III that is irrigated by surface irrigation from the Tanganda river. The decision to change from a wholly surface gravity system, to a system with boreholes and a pumped sprinkler network, was made after realization that there was insufficient river water to sustain a large area of 262ha (Mutema design report 1994 pp 5). Another reason for implementation of sprinkler irrigation in Block I was that it was considered too sandy to be under surface irrigation. However Block II is mainly gentle sloping heavy soil that is ideal for surface irrigation: therefore up to now the farmers in this particular block wish for surface irrigation. It is believed that the use of borehole water could have significantly influenced the adoption of sprinkler irrigation at Mutema[3], which occurred at a time such systems began to be widely promoted in other parts of the world.

The Mutema irrigation system has a one-step or direct pumping from the borewell to the sprinklers, as per original scheme design. Table 5.2.1 summarises the chemical attributes of Mutema borehole water**.** According to the late Mr Horsefield, who co-ordinated scheme management activities from 1980 -1988, the salinity of the borehole water was identified during the development stages. It was then recommended that borehole 4 would always work together with borehole 3 which was of lower salinity in order to effect dilution. Use of highest salinity borehole number 4 on its own was discouraged. It was probably due to this need to mix borehole waters that the whole system was designed as a closed combination system where water would go to the whole system from an initial common main AC pipeline situated after the junction of the pipelines from borehole 3 and 4. It was technically possible to design BH 3 to supply one block and have the other three boreholes supply the other, using borehole yield considerations alone.

[2] The sprinkler system was also developed in the period 1968 to 1977 when the greatest expansion of irrigation in Zimbabwe occurred, when the total formal irrigated area (including commercial farms but excluding *bani*/dambo) increased from 60000 to 150000 ha (Svendsen and Rukuni 1994, pp13).

[3] Evidence from government documents of the time show significant discussion on the merits and demerits of surface and sprinkler systems as discussed for Nyanyadzi and Chibuwe (see Chapter 2). In both these schemes it was decided not to go for sprinkler irrigation. However Manzungu (1999, pp48) reports that Chibuwe Block E was initially developed as a pilot sprinkler system in 1958 and later converted to a lined surface system in 1965 due to high operational costs.

Table 5.2.1: Mutema borehole water quality details

Item	B/H 1	B/H 2	B/H 3	B/H 4	B/H5
Calcium (Ca)	44.8	35.2	81.6	77.6	76.8
Magnesium (Mg) (ppm)	29.6	20.0	57.2	51.9	50.4
Sodium (Na) (ppm)	22.5	27.1	140.0	152.0	86.3
Carbonate (CO_3^{2-})(ppm)	Nil	---	---	---	0
Bicarbonate(HCO_3^-) (ppm)	278.0	274.5	584.0	512.0	549.0
Chloride (Cl^-) (ppm)	9.09	31.2	85.2	204	42.6
Sulphate ($S0_4^{2-}$)(ppm)	44.1	---	178	53.9	126
Conductivity (μmho cm^{-1})	623	445	1335	1424	1291
pH	8.8	6.7	8.5	8.0	8.8
Sodium Adsorption Ratio	0.4	0.4	1.4	3.3	0.9
Residual Sodium Carbonate	0.13	0.5	0.8	0.2	1.0
Ca/MG ratio	0.9	0.8	0.9	0.9	0.9
Source: Chemistry and Soil Research Institute DR&SS (1993)					

The salinity levels observed in the wells are high enough to reduce the yields of some of the crops grown (FAO 1976, FAO 1977). Table 5.2.2 gives the expected yield reductions and leaching requirements for the crops grown at Mutema (Mutema Design Report 1994 pp12), and also shows the yield reductions for some crops as reported by the IMC.

Table 5.2.2 Leaching requirements and yield reductions for Mutema irrigation based on borehole water quality

Crop	Conductivity of irrigated soil (EC_e) dS m^{-1}	Conductivity of irrigation water (EC_w) dS m^{-1}	Salinity tolerance 50%yield reduction (EC_e) dS m^{-1}	Leaching requirement LR= $EC_w/(5EC_e-C_w)$	Farmers' observed % yield reduction 1972-1992
Maize	0.41	1.33	5.9	0.05	60*
Beans	0.38	1.37	3.6	0.08	80**
Tomato	0.38	1.37	7.6	0.04	
Groundnuts	0.41	1.33	4.9	0.06	
Onion	0.38	1.33	4.3	0.06	12
Cotton	0.41	1.33	17.0	0.02	
Wheat	0.38	1.37	13.0	0.02	
Source: Field observation, Mutema Design Report (1994), *yield reduced 30 to 10bags/ha and **yield reduced 80 to 14 bags/ha based on informal interviews of farmers and IMC members.					

Mobile Electric (a Mutare based company) designed the overhead scheme in 1973, as two blocks of 90ha area each linked to all the four boreholes. The boreholes were linked to dilute the salinity of the higher yielding boreholes no. 3 and 4 using the relatively low yields of the higher water quality boreholes no. 1 and no. 2. A closed system may also have been justified considering the need to allow other boreholes to supply other scheme areas during any breakdown, or reduced demand. The four boreholes also have different capacity as shown in table 5.2.3 and therefore there was no possibility of spares being common. However, the system is reported to have worked well for over 15 years. According to local Agritex staff the lower yielding boreholes 1 and 2 gave problems first. Attempts to repair them were made in the early 1990s. Borehole 1 near the Tanganda River collapsed in the early 1990s and DWD tried to resuscitate it in vain.

Table 5.2.3 Mutema Boreholes yield and pump details

Borehole No.	Yield ls^{-1}	Motor size Type and size	Depth (m)	Pump Type and size	Year Installed	Status
1	35	54 HP	26	Hawker J Mono pump	1973	Collapsed 1980s, washed out by Eline
2	21	30 HP x 2	30	Monopump 'Sl.D.D.l	1973	Collapsed 1980s, washed out by Eline
3	85	200 HP	26	Sangus turbine	1973	Working – leaking shaft worn out
4	54	75 HP moved nearer to save R. due to salt water.	26	Hawker Monopump	1973	New replacement borehole washed out by Eline in yr. 2000
5	7	35 HP	35	Tinto Monopump	1999	Low yield not being used
Source: Agritex and DWD provincial records						

The distribution and application subsystem comprises asbestos cement (AC) main field pipelines supplying water to hand move aluminium laterals through hydrant control valves as per original design as given in figure 5.2.1. Farmers are responsible for lateral pipe changes under the supervision of water bailiffs. The Mutema farmers are generally reluctant to talk about the problems experienced in the early days and how discipline was constituted. They contend that they had more reliable water supplies. Materials were in good condition then and immediate maintenance took place when required, supplied by the agency. Their major complaint was that the pipes were very heavy, as at that time the pipes including the risers were made of galvanized iron (GI). They were however very robust. The first rehabilitation of the distribution and application subsystem occurred in 1987 when aluminium (Al) pipes and some a single nozzle sprinkler were introduced. Farmers were generally not happy with these changes and they have used every available forum to castigate what happened in 1987.

The old distribution network designed by Mobile provided for water to be irrigating both blocks at one time, with all boreholes discharging into the system. This required that all pumping plant be operational. The system builds pressure gradually. If however any one borehole is not working it has to be isolated to prevent water from flowing into that borehole leading to loss of system pressure[4]. The farmers are acutely aware of this network operation and they always check for such outflows to old boreholes when pressure is low. At times they have to stand by the old well and listen to sounds of water movement to ensure that it is not taking in flow from the operating wells. The field mains are supposed to be maintained by Agritex according to the farmers, and vice-versa according to the new Agritex farmer management concept.

Government institutions were responsible for paying electricity for Mutema irrigation scheme from the beginning of borehole pumping until the year 2000, when Agritex and DWD advised farmers to start making contributions.

[4]In fact it was noticed in December 2000 during the repair of cyclone damage in block II, that the old pipe from this well was always taking flow to the now defunct borehole number 1 which had to be plugged off before pressure testing the system.

Crop production and marketing

At Mutema the main summer crops grown are maize, groundnuts and cotton, and the main winter crops are tomatoes and wheat (see Table 5.2.4). Beans are not a major crop due to salinity.

Table 5.2.4 Crop grown at Mutema

Season	Area%	Crop
Summer	30	Maize
	12	Groundnut
	56	Cotton
Winter	80	Tomatoes
	15	Wheat
	5	Onion, beans etc
Source: Field observation and Agritex records		

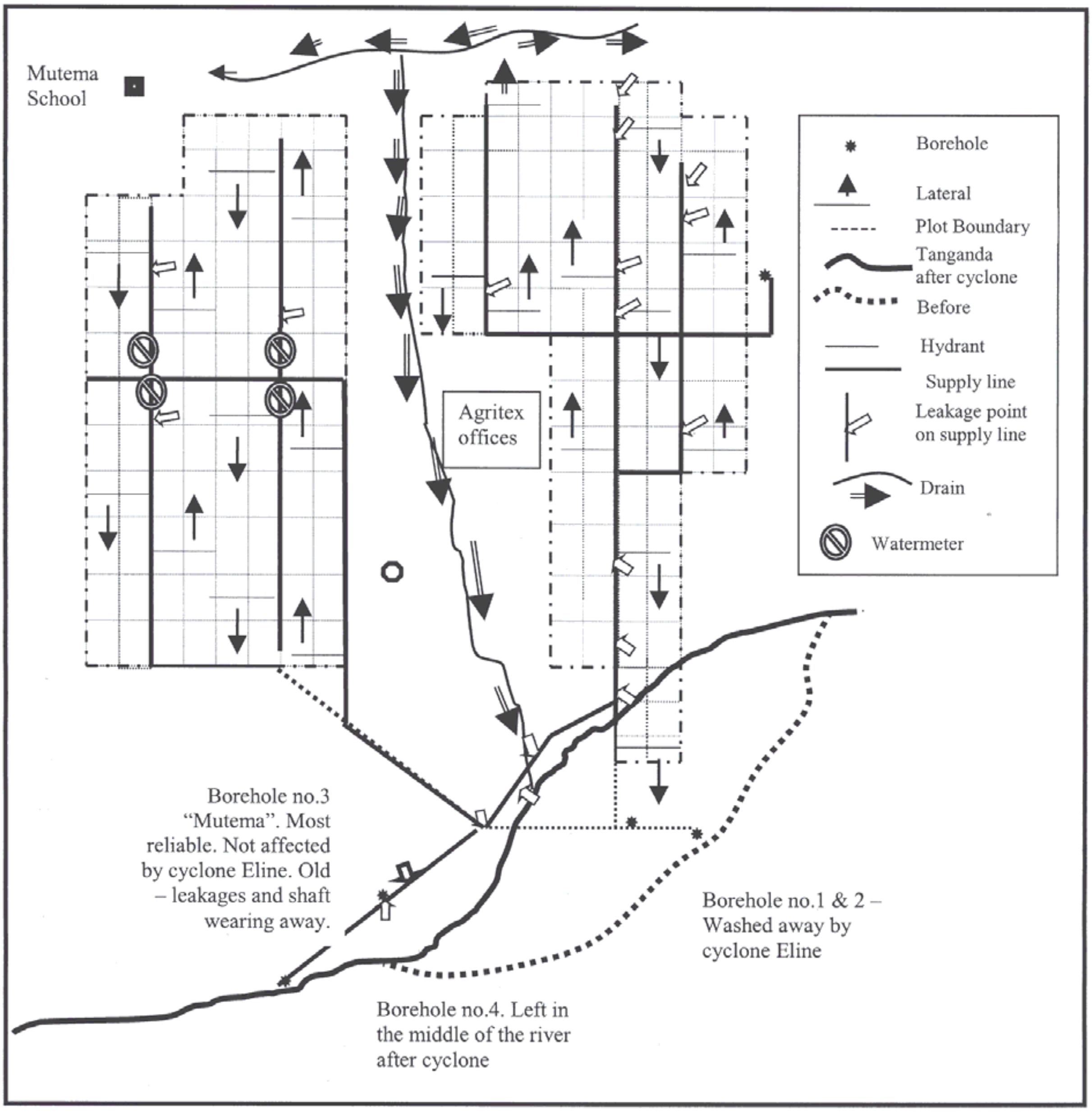
The livelihood crops grown at Mutema like most other schemes are maize, wheat, groundnuts and vegetables. Farmers at Mutema plant most of their maize and groundnuts crop with the rains in November and December, to increase their crop water security as observed in tail end blocks at Chakowa. The scheme is located far away from major roads further depressing the green maize market present at Chakowa and Deure. While Mutema farmers would like to plant early they normally plant late, due to unreliable water supply.

The colonial government was acutely aware of the viability problems of growing wheat with pumped irrigation and used a number of strategies to secure a sustained production of this food crop. The opening up of the Middle Save scheme adjacent to Mutema, with large areas grown to wheat by settlers with significant government concessions and half the area put under ARDA a government institution, was a direct response to this problem. Even commercial farmers who produce the main wheat crop find it difficult to break even with wheat and still derive a livelihood out of farming. The price of wheat is negotiated on an annual basis with central government. This is due to the national importance, of this increasing popular food crop. This maybe one reason why electricity costs for Mutema never passed to smallholder farmers during the colonial era.

The main commercial crops grown at Mutema are cotton and tomatoes. Cotton was one of the first commercial crops introduced on irrigation schemes. Its introduction was accompanied by an elaborate support through extension, training, handling and marketing facilities as evidenced by structures at Chakowa. Recently the cotton crop has also received substantial financial support on individual farmer basis from competing private buyers. They provide complete loan schemes covering inputs like seed, protection chemicals, fertilisers, labour costs, transport and packaging. There are two cotton depots in the vicinity. The cotton crop is both reasonably tolerant to salinity and can withstand unreliable water supply and thus acts as the "default crop" that Mutema farmers can grow.

At Mutema the impact of the early tomato crop sold on the table market is insignificant compared to the main crop grown after harvesting the summer crops. Cotton is harvested later than maize and groundnuts and determines the latest planting dates for tomatoes.

Fig 5.2.1 Schematic diagram showing Mutema irrigation scheme layout



The tomatoes also need transport to compete at the Deure table market. Tomatoes occupy almost the whole scheme at Mutema in winter. Virtually all the crop is taken for canning in normal years[5].
It is only in the dry years that Mutema farmers yield to pressures to sell tomatoes to buyers who supply the table market, as in 1991-92.

[5] The commodity production of canning tomatoes is characterised by group contracting whereby a scheme, management block, hydraulic or other formal or informal grouping is contracted to grow a certain area. There is currently one main canning company in Mutare, whose agents supply seed annually to growers under a verbal contract to sell all produce to the company. They also provide transport to field-edge and deduct transport costs from sales. The company buyers or agents monitor production during the growing season. During harvest and collection the IMC monitors, records, follows-up and collects bulk payment for tomato deliveries to canneries, deducts individual expenditures and effects individual payments.

At Mutema the Irrigation Management Committees (IMC) takes care of the contracting issues because virtually every farmer is involved in contract tomato production. Their performance on this particular task has a strong influence on their ability to retain office during the elections. Any misunderstanding normally leads to sanctions by way of loss of confidence and loss of votes. Trusted individuals can hold office for two terms as shown in table 5.3.4. The persons responsible for collection of payments for scheme tomato deliveries to canneries are paid transport and subsistence allowances consistent with the actual cost of travel and food.

Among buyers, Mutema, and lately Bonde, are seen as among the best tomato producers in the Save valley. A number of factors have been advanced among which is the lack of opportunities for side marketing and use of sprinkler irrigation. Use of sprinklers suppresses mites and is believed to favour the early and continuous adoption of a good spraying program against blight. Sprinkler irrigation also causes evaporative cooling that lowers high temperatures and raises low relative humidity that cause poor growth and production in tomatoes (van Zyl and Bredell pp106)

5.3 THE MUTEMA MANAGEMENT SUPPORT SUBSYSTEM

Mutema like other government management schemes Chakowa and Deure shared a resident white manager with neighbouring Tawona. The black manager appointed after independence left to become a freelance consultant after becoming a supervisor for a short period. The current staffing position is shown in table 5.3.1.

Local technical staff: Extension services, water bailiffs and pump operators

The extension service at Mutema comprised one officer and two extension workers. The Extension Officer was also responsible for Tawona irrigation scheme, and was appointed permanent team leader for the surrounding dryland area. The functions and activities of the extension staff in farmer training are similar to those described in Deure. During the study period there were no field days at Mutema. Most of the farmers' gatherings were centred on finding ways to improve the water delivery to the scheme.

Table 5.3.1 Summary of Agritex services at Mutema

Description	Block 1 (sandy)	Block 11 (clayey)
Study Area (ha)_	90	90
No. Of farmers	102	104
Hydraulic blocks No.	1	1
No. Extension officers	1(shared)	1(shared)
No. EWs	1	1
No. Water bailiffs	2	2
Maintenance staff No.	5	5*
Maintenance equipment	Old, unusable	Old, unusable
Administration staff No.	3 (shared also services Tawona)	3 (shared also services Tawona)
Maintenance fee level	$145/ha	$145/ha
Maintenance Fee payment in 1999	Fair	Very few
Source: field study* used to be 15 for each block		

Local extension staff members have virtually no reference material to inform their everyday irrigation practice. The farm management handbook is not available to this level of staff. The irrigation manual prepared by FAO and Agritex has mainly been used by designers and is also sold by Agritex. The manual predominantly deals with draghose sprinkler irrigation design procedures and has superficial coverage of operation and maintenance issues of overhead schemes. The old irrigation handbook, that had more material on conventional sprinkler systems like Mutema and their management, is no longer being produced. Therefore there is very little technological and water management information, and this is reflected in their operation and maintenance practices. They have no pressure gauge or vernier calipers or other measuring devices or instruments to verify sprinkler parameters. They can deal with minor issues: an example they always point out, is the ability of their workshop to attend to springs if they malfunction so that the sprinkler keeps turning. Agritex offices and extension workers' houses at Mutema were electrified in 1970 when the borehole pumps were commissioned.

Water bailiffs are answerable to the water controller, locally referred to as the senior water bailiff. No water allocation sanctions are imposed relating to maintenance payment as observed at Deure. The senior water bailiff at Mutema covers for any water bailiff in emergency, as observed at Deure. The senior water bailiff is the most informed individual in the water management of the whole scheme. He determines the number of laterals in use, length of each lateral and positions of laterals that should be operating at any one time depending on the water requests farmers make to the water bailiffs. He also determines the duration of pump operations for any period. The senior water bailiff is a locally renowned farmer.

Agritex staff members do not keep records of irrigation events. The blackboard at the offices that shows irrigation turns only got used during this study. This is a board with all plot numbers at the offices that the irrigation managers used to fill in to assist in allocating irrigation turns.

The duties of the water controller at Mutema resemble those of the water controller at Deure even though the systems are technologically different. The main difference seems to be the relatively weak technical capacity of Mutema extension staff to provide required practical backup in attending to problems experienced at the scheme as per system requirements. There is no local capacity to immediately follow up and rectify faults or problems in the system, as illustrated in the canal breach at Deure in chapter 3. The Deure technology is simple and understood by the local extension staff providing technical support. The extension staff at Mutema are not in a position to guide in the repair of pipes, valves as other system components as required. The duties of the senior water bailiff are summarised as:

- Requesting pump operators to switch on and off for adjustment of laterals to match actual farmers irrigation requirements and in emergencies such as pipes burst
- Following the main pipelines and checking for problems in the pipe network and making reports to the supervisor
- Following up water to outlets of WB. This is both for water delivery and adjustments. He checks laterals operating in each hydraulic block.
- Working with IMC committee and gives recommendation to avoid conflict.
- Providing information on the pumping plant condition and capacity to different block committees and the supervisor.

The EWs and IMC can only advise and ensure that blocks rotate flow to ensure equity.

There is no capacity to take action in repair of major pipe bursts or pump breakdowns. The DWD was responsible for the operation of the Mutema boreholes as discussed in section 5.4. The main reason cited for under performance of the water delivery subsystem (WDSS) was the low budget allocation, see table 5.3.2: funds were only enough to cover staff salaries and a few basic running costs. There was no provision for maintenance of borehole pumping plant. The schemes tended to rely on Agritex allocations meant for in-fieldworks and development at Mutema. Inadequate maintenance resulted in poor water deliveries that in turn affected cropping programs.

Table 5.3.2 Requirements and actual allocation for Mutema

Year	Estimate Required	Actual Allocation	Percent
	$	$	
1996	961000	202000	21
1997	1934300	245290	13
1998	2255000	160000	7
1999	1800000	-	
2000	2211000	-	
Source: ZINWA records			

All the local staff can do is to send word to DWD and Agritex provincial offices to act on a breakdown. It is believed that one of the strategies being adopted by the ZINWA management is to open a repair workshop in the middle Save area, to attend to breakdowns. The problem though has never been the communication of messages between Mutema irrigation scheme and DWD Mutare office[6]. It was mainly created by the institutional arrangements and its needs for sustained quality delivery - technical capacity, capitalisation, spares backup, skills, knowledge, motivation, and all that leads to quality water delivery to a resource poor client. **The resource poverty is not only in financial capital but also in human, skills, knowledge, management and other capacities to shape service delivery to match a desired cropping program.** The inability of local institutions to respond positively to the information and recommendations of the water controllers has resulted in their functions not being appreciated. Most new piped schemes being developed lack this support structure, as will be discussed for Bonde and Mpudzi in chapter 7 and 8.

Infrastructure maintenance support

At Mutema an EW is responsible for a 90ha block or hydraulic unit or module. This falls within the planned ratio of an average irrigated area of 70ha or 50 to 100 farmers to one EW as given by a former deputy director responsible for field or extension services in Agritex. A water bailiff also operates in each block. The water bailiffs do some minor repair works to valves. The Mutema workshop although originally built, equipped and stocked well, has not had any attention for a long time. There is no functional complement of tools to do any meaningful repair works. In the canal systems foremen, handymen, builders are employed to plan daily work activities, allocate tasks, control and be accountable for equipment. These positions are not elaborated at Mutema and other overhead schemes as will be evident in chapter 7 and 8. Therefore there is little facility to care for the equipment at Mutema.

An inventory of the scheme's existing artefacts and their condition was carried out in year 2000. Mutema like other old government schemes Deure and Chakowa had old tools and equipment including vehicles as shown by a snapshot inside the workshop in photo 5.3.2.

[6] The telephone linking Mutema to the outside world works reasonably well, in contrast to the local line linking the Agritex office to the borehole operators that has been down since the early 1990s. Agritex staff ensured that problems were always reported to their provincial head on time. The provincial head of Agritex in turn contacted his counterpart in DWD. The resident engineer during the study was always ready to provide transport need to ensure that deliveries happened in the shortest period of time.

Photo 5.3.1 Snapshot of the inside of the Mutema irrigation scheme workshop

The scheme has no permanent vehicle, making it impossible for any workshop to be contacted in towns like Chipinge to facilitate the repair of specialised equipment, parts or components. Virtually all equipment is obsolete and the yard is full of old pipes and pieces of equipment. There is no equipment to check for proper functioning of sprinkler systems. Yet, policies of irrigation management transfer imply that farmers and local officers should have adequate equipment and be able to use and manage this. IMT at Mutema implies that farmers would be required to organise and source workshop equipment that government itself never managed to source or use.

Administration personnel provide clerical services to civil servants at Mutema and they also cater for the neighbouring Tawona irrigation scheme. Immovable infrastructure like houses, offices, storeroom and workshops belonged to the Ministry of Local Government Public Construction and Housing (MLGNH) who constructed and maintained the infrastructure. DERUDE and later Agritex paid rentals for occupying these buildings. The current shift in ownership and maintenance of infrastructure now requires Ministries and departments to source funds directly for construction and maintenance from the Ministry of Finance. It is not known how this infrastructure will be partitioned between the Ministry of Rural Resources and Water development and the Ministry of Lands and Agriculture in the ongoing streamlining of roles, functions and responsibilities.

Irrigation management committees

Each block has an executive committee of main office bearers comprising a chairman, a vice-chairman, secretary, vice-secretary, treasurer and some four committee members. The committees have each a constitution and bye-laws (see Appendix 2). The block committees are responsible for the day to day running of their blocks. They work directly with their extension worker and water bailiff in water allocation between individual farmers. They are responsible for conflict resolution at block level. The play an active role in marketing of tomatoes at block level. The block committees have since 1999 taken a leading role in the collection of electricity fees for their blocks. They are increasingly taking a leading role in the sanctioning of electricity payment defaulters.

The block committees elect members of the main committee who also have the same office bearers that is a chairman, vice-chairman, secretary, vice-secretary and treasurer and committee members. The main committee presides over the activities of all blocks. They are responsible for the coordination of the individual block activities. They work closely with the senior water controller in water allocation across blocks. The main committee is responsible for the payment of the overall scheme electricity account. They therefore play a role in ensuring that the different blocks are each contributing their share of the power costs and may act decisively to stop defaulting blocks from irrigating as occurred after cyclone Eline. They stopped sandy block farmers from irrigating even though their infrastructure was operational because most of them were defaulters in electricity payments. They could accelerate the scheme debt during the time the better-paying clay block was under repair. The main committee is in overall charge of the tomato marketing arrangements.

At Mutema there have been frequent elections and a clear record of main office bearers over the last twenty years are shown in table 5.3.3.

Table 5.3.3 Irrigation Management Committee main office bearers at Mutema

Period	**Office**		
	Chairman	Secretary	Treasurer
1980-84	Mr.B. Dhambiye	Mr. G. Mugeyo	Mr. D. Masunungurwa
1984-92	Mr. Masunungure	Mr. V Sukuta	Mrs. S. Munandi
1992-96	Mr. Chijokwe	Mr. Sukuta	S.Mahlupeko
1996-2000	Mr. M. Mhlanga	Mrs. Chijokwe	S. Mahlupeko
Source: Agritex and farmer records and field observation			

Although elections are held every fourth year there are individuals who have held office for three terms. This is due to trust in them, or lack of alternatives. The clear record, which the farmers are proud to show to outsiders, contrasts with the situation observed at Chakowa and Deure. Taking office in Mutema committees is both an honour and demanding. High calibre persons are elected. The chairman during the study was a former headmaster with a good track record.

At Mutema, the IMC plays a significant role in tomato marketing. The roles of the Mutema IMC in water delivery and maintenance have traditionally been marginal, but since the year 2000 the Mutema IMCs are being forced to take a leading role in payment of electricity bills and in operation and maintenance of the water delivery system. The collection and payment of electricity bills by the IMCs is one of the primary roles farmers are expected to take at an early stage in the Agritex programme of handover of schemes.

The traditional leadership at Mutema is involved in conflict resolution as documented by Vijfhuizen (1998). They are specifically effective where conflicts involve locals and farmers only. Where conflicts involve government officials they are not very effective. The traditional leadership also plays a part in mobilising resources from local government and negotiating for assistance. They are the final authority in scheme level plot allocation at Mutema. They provide guidance in dealing with materials and artefacts that have a strong bearing on belief systems such as sacred trees and burial sites.

The sprinkler blocks 1 and 11 at Mutema have the same area and almost the same number of farmers with their only fundamental difference that one block is predominantly sandy and the other is clay soil. The sandy block farmers referred to soil fertility problems in a manner similar to Chakowa. The farmers, AGRITEX and local councillors want equity to prevail across the two schemes through equal access to water at all times and through the same irrigation practices irrespective of the soils. There is therefore no block specific scheduling of water turns. Irrigation turns are shared equally between the two hydraulic blocks shown in figure 5.2.1. The high level of "equity" observed at Mutema is due to these across block operations. The water application processes are simple at Mutema scheme, with almost all responsibility resting with Agritex.

The common electricity bill is divided equally among all farmers in the two blocks. However, this caused serious problems when cyclone Eline floods damaged the conveyance to the clay soil block. The farmers in the sandy soil block were asked to stop irrigating until the whole scheme had been rehabilitated. All farmers were telling outsiders that this was a joint agreement that was showing solidarity and unity at the scheme. When really pressured to let the sandy block with all equipment intact irrigate, the clay block farmers revealed that the majority of the sandy block farmers were defaulters on electricity payments. Allowing them to operate on their own would fuel the scheme electricity debt. Two main currents informed the Mutema farmers' view on their role in maintenance of infrastructure. Historically they had been used to government maintenance and therefore any departure from that was perceived to be a failure on the part of government. Hence they were quick to ask what role government officials would continue doing at the scheme if they were to take over maintenance. The farmers also raised the point that a reliable water delivery was necessary for them to take over maintenance. They would not have capacity to finance maintenance unless they had a secure production system. The failure of government institutions to meet the later conditions became a stumbling block in initiating any meaningful maintenance take over at Mutema. The take over of operational costs did go through the same negotiating processes. When electricity was cut off and the pumps were functional, the IMC was pressurised to mobilise farmers to pay in order to survive[7].

The IMC was not involved in repair of laterals or sprinklers. Responsibility seemed to cascade straight from the state to the individual farmer. There was no co-operative effort to attend to equipment during the study period. The workshop was meant for government staff. Farmers believed that they should simply take equipment to be repaired at the offices. If the workshop could not service them then it had to close down as it was serving no purpose. The farmers would then find alternatives knowing full well that nobody was charged with that responsibility. This is why the EWs advocacy of the surface irrigation came in.

5.4 THE PRACTICE OF GROUNDWATER PUMPING AT MUTEMA

Borehole operation

When all four boreholes were operating well all farmers could irrigate as per their lateral movement, with both blocks irrigating at the same time. When laterals started leaking excessively in the 1980s, the farmers started taking turns to irrigate between the blocks. The situation deteriorated in 1990, when borehole number 4 started giving problems, to such an extent that one block started extending irrigation time beyond the normal 13 hours of pumping per day. One borehole supplied water to the two blocks on alternate days, thus effectively doubling the irrigation interval. With breakdowns the irrigation interval increased from the strict design interval of 9 to 18 days. Irrigation cycles of 30 days became common during the peak period stretching from November to January. These cycles result in no yield for most of the Mutema maize crop whether planted early or late. Unlike the Chakowa case detailed in chapter 3 even the late maize crop suffers from stress due to the severity of moisture stress experienced at Mutema which lies in a comparatively drier zone that is natural region 5. Cotton survives and gives reasonable yields.

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[7] Ironically Mutema area is one of the schemes where the community has electrified homes. It was therefore difficult for the farmers to have the comfort of electricity at home when crops were wilting due to lack of electricity.

However, the borehole management also hit some cultural concerns. The boreholes are also located in the areas where people did not ordinarily reside at Mutema. For the community these low-lying areas were not inhabited by "normal people", but were a zone for ghosts and spirits, where bodies were also buried. The community is thus virtually not in a position to enquire or talk about the water mobilisation technology "they have been living with" for the past 35 years. They would like government officials to provide solutions.

Borehole maintenance at Mutema was provided by the workshops' section of the DWD (now ZINWA). A senior technician based in Mutare controls the workshops and is also in charge of pump stations at Chibuwe, Tawona, Bonde, Nenhowe and Nyanyadzi. According to the extension workers, the water bailiffs and the farmers the pump attendant sends requests for assistance and waits until someone comes. DWD staff initially provided maintenance on a periodic basis but later this became sporadic. The pump attendants could no longer be sure when to expect a visit or service after a request. Staff from DWD Mutare came to the schemes and carried out repairs. They normally rewound motors, changed bearings and added oil where required. They had also changed the shaft for borehole No 3.

The pump attendant pointed out to the need to replace shaft and bearings for borehole 3 in early 1999. The shaft had worn out to a visible thin section where it rotates in contact with gland packing. Water was leaking out a rate of about 0.25 l s^{-1} as measured on 14/11/2000**.** According to the pump attendant any attempts to put in gland packing were failing to stop the leakage due to the excessively thin shaft. The pump operator also expressed fears that the "Mutema" shaft might break anytime and destroy people's livelihood. ("*Iko zvino shafuti nezvayaita izvi inogona kungoguduka nguva yese yese, ikauraya zvirimwa zvevanhu")*. Since early 1999 his request for replacement of this component have not been answered. The pressure gate valve was losing about 0.5 l s^{-1} through leakage on the same day. It is normally supposed to release water only when pressure is too high i.e. to reduce it to the normal working pressure. So now pressure is always lost. Farmers did not know of any plans to attend to these problems.

Due to these problems farmers interviewed generally thought that the only viable option was to replace the borehole pump units with new ones. They are not worried about the present state of the borewells themselves and how this may affect the performance of the new pumping units. This presents a rather difficult technical dimension for replacement works of boreholes. Experts generally recommend that new pumps be fitted into new wells unless a thorough cleaning shows that an old well is usable. Farmers' knowledge of river pump installations at Tawona and Middle Save estates, their immediate upstream and downstream neighbours respectively, have convinced them that all that is required is to replace the pump and motor unit in the same well. In the Mutema farmers' view the drilling of new wells is an unnecessary exercise that was unnecessarily delaying their realisation of a better water supply. Government officials on the other hand were convinced that this is a worthwhile solution if the water delivery is to be secured for a reasonable length of time. Unfortunately the aquifer has quality problems that further complicated the implementation. Thus the gap has widened between farmers and government officials centred on the concepts and perceptions of sustainability of sophisticated technology in a less developed environment.

Pump Operation practice at Mutema

Borehole pump attendants or operators are permanent employees of DWD (now ZINWA). They receive requests to open and close pumps from Agritex Water bailiffs. They record the number of pump operation hours for each pump unit and send the data recorded to the province. All recorded data is sent to the Mutare office and no duplicate is left at the pumping station. If the data is misplaced or gets lost there is no source of records to fill the gap. This has occurred with Mutema borehole pump records. The technician in-charge spent three months trying in vain to locate the missing data. When I asked him why they had no duplicate, he explained that they used to do that but stopped as a cost cutting measure. At provincial level the data is simply filed, according to the staff responsible for handling the records.

There was no evidence of the data ever being used either to check borehole or pump performance or maintenance status, as specified in design handbooks. In fact the Mutema pump attendant has always entered a value of 400 ½ for the operating pressure. However when we checked mid November 2000 with the actual gauge reading we discovered that the half actually meant the gauge was between a pressure of 400 and 600 kPa. In his own simplicity he therefore entered 400 and to note that it was half way between 400 and 600 he recorded ½ so the recorded pressure is 400½ kPa. He has done this for over seventeen years without someone noticing.

Agritex keeps no records of pumping hours at all. No one seems to know the exact flow rate. The pump attendants and Water Bailiffs have more than fifteen years experience operating in their respective positions. The pump attendants have changed mainly due to old age and retirement, and some have been brought in from Mutare offices. Their educational standards and training are not known locally. They work independently of the farmers but switch on and off as per the recommendations of the water controller of Agritex who oversees requests from farmers for water. However, they were always at the pump stations. Pump attendants do not keep electricity consumption records. The provincial offices of both Agritex and DWD do not keep records of the electricity consumption or payment. The electricity billing is based on individual borehole power consumption. However borehole 3 has its own transformer. In fact we discovered that the borehole number used by Agritex and DWD differ from ZESA power point references[8]. Agritex and DWD borehole No. 3 is ZESA point No.2. There is no map to show these systems of referencing. The Extension Worker however seemed to understand the different reference systems. Perhaps this seeming confusion and need to refer to them for explanation was a source of power.

Water meters on field sub-blocks installed by Agritex in 1996 were not used and in some instances not known to staff. The provincial DWD officials say that the original water meter was removed sometime back, but were unsure when Agritex also bought new additional water meters that were installed on each block. They could not be installed in time for this study due to cyclone Eline disruptions. Borehole No. 3 has a design peak operation time of 13 hours per day. However during mid November 2000 it was learnt that due to excessive leakage in the whole system the pumps, which were only irrigating the sandy block 1, had to run three shifts of 5 hours each instead of the normal 2 shifts of 6 hours each. This results in increased night irrigation with its attendant problems of poor sprinkler operation monitoring.

5.5 DELIVERY PERFORMANCE AT MUTEMA

The RIS given by pattern of the pumping delivery and irrigation water requirements during the study period is given in figure 5.5.1. The pump delivery was calculated from pumping time records made by the pump attendant at the only operational pump station. The irrigation water requirements were based on the calculated needs of the crops planted by the farmers. These graphs indicate that the pump unit was not able to provide a consistent delivery for the

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[8]This difference in naming pump stations and billing stations was also observed at Bonde. The farmers, Agritex and DWD have each their own reference numbers that they use. ZESA uses its own code numbers.

scheme. The system also failed to meet peak water requirements even in the winter months, unlike most schemes observed in this study, as well as those considered by Makadho (1994).

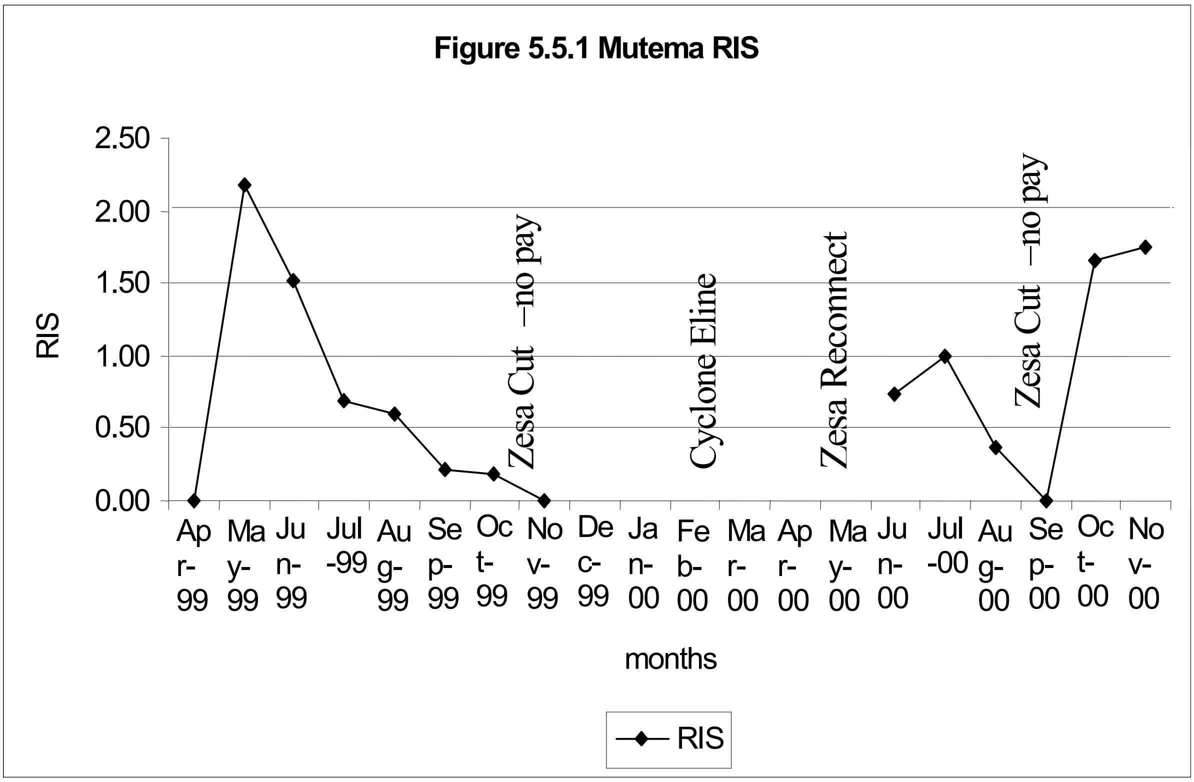

Figure 5.5.1 Mutema RIS

After electricity payment and reconnection, in the first months of irrigation from end April to the end of July 1999, supply exceeded demand mainly as shown by RIS above unity with a peak in mid-June. This was due both to water that was used to wet the land to facilitate ploughing the low demand of the young crop and a smaller planted area as generally farmers took time deciding whether or not to plant due to unreliable water deliveries. As from mid June to end of July the excess decreased culminating in a deficit from August to October 1999. Electricity was then cut off and the scheme was damaged by cyclone Eline. The winter 2000 season started late again and this time the water supply never exceeded demand. Again electricity was cut off due to non-payment after two months of irrigation. This meant the two successive winter crops all got disrupted by electricity cuts. The summer crop got no irrigation at all again due to an electric power cut in November 1999. The periods of pumping were also characterised by low RIS after most of the farmers had planted. This was due to the increased demand against a constant supply from the one operational borehole that lead to a constant supply of water being increasing spread over a bigger area of a crop with increasing water requirements. The net result is deficit irrigation with long irrigation cycles being broken by power cuts. Poor water delivery led to the hostility and non-cooperation with Agritex staff including the researcher as discussed later.

Tomatoes in winter and cotton are the only crops that the farmers can bank on, as they are fairly resistant to moisture stress. Dry conditions also tend to control fungus diseases.

5.6 ATTEMPTS TO IMPROVE WATER SUPPLY

The problem of poor water supply at Mutema has been approached from several perspectives:

i) To drill and equip other wells so as to replace the aging outfits that is “replacement approach”;

ii) To provide a river pump and booster unit that would utilise water from the Osborne dam - that is the "re-design approach";
iii) To build a dam upstream of the river to stabilise the Tanganda flow – this was not followed in the short term due to lack data on dam site selection.

A fourth option of initiating a gravity conveyance canal on the right bank to supply water to most of the Middle Save schemes will be discussed under the Musikavanhu case study in chapter 6.

The first option got priority because it resulted in "an easy addition" of borehole modules into an existing closed loop pipe distribution system. As the old boreholes were to be retained it was envisaged that the system would actually become more reliable and even more flexible. The major assumption behind this approach was that the Mutema borehole water was coming from a confirmed aquifer[9]. Unfortunately it later transpired that there were no records of any prior groundwater studies done before development of the original Mutema irrigation boreholes. The only records available relate to boreholes developed for domestic water supply in the area[10].

According to the head of groundwater branch the expected working life of a borehole is 30 years for steel and 60 years for stainless steel casing. If pH ranges from 6.5 to 7.5, then the borehole is likely to have optimum performance and any casing material can be used. If the pH is higher than 7.5 there is a problem of precipitation of salts that clogs the packing and screen openings. Stainless steel or PVC casing is used where the pH is lower than 6,5 to avoid corrosion. Table 5.2.1 shows that only borehole number 2 has a pH less than 7.5 suggesting that all the original boreholes drilled at Mutema are susceptible to clogging of openings.

In 1992 the DWD drilled wells close to existing boreholes 1 and 2 near the Tanganda River as a first priority, due to the low salinity of the existing wells. The wells had low yields and were therefore not developed further. Wells were then drilled near BH 3 and 4, but closer to the Tanganda River, in an attempt to get more yield while still in the low salinity zone. One had a reasonable yield, and was subsequently equipped, but was damaged by cyclone Eline in the year 2000. The power authority ZESA is now reluctant to extend its line to the borehole, because it is within a flood zone. Electricity has to be conveyed to the well by means of an armoured ground cable as was done for the Nyanyadzi South boreholes.

Other boreholes were then drilled very close to the Save River. These wells had very high yields but the water was brackish. They were therefore not developed[11]. In 1996 yet another well was dug near the old borehole Number 1 but again proved to have a low yield after commissioning. A Mutare based irrigation company won the Agritex tender to equip the well. They installed a submersible pump but the yield was only enough to pressurize one lateral of 15 sprinklers. After these efforts the borehole replacement option was dropped in 1998.

Agritex and DWD met at the DWD offices in early 1998 and a verbal understanding was reached whereby DWD was to design a booster pump station and upgrade the Tawona main

[9] The DWD groundwater branch was requested to use their experience to site, drill and test up to five boreholes in the early 1990s. The head of the groundwater section confirmed later that there was no exploration done using recommended scientific methods as the area was known to have an aquifer, and no specific requests were made for groundwater investigations (personal communication – 09 March 2000).

[10] Current studies show that the domestic water boreholes also have high salinity levels (Motsi forthcoming).

[11] While it is technically possible to use brackish water for irrigation but there is need to use micro-irrigation and pay particular attention to water management. It was felt that the current levels of management on the existing schemes would not justify support such a venture.

river pump station[12]. Agritex was to provide the canal link between the main river and the booster pump station and the link from the booster pump station to the sprinkler system. The DWD designed the booster sump, which was constructed by Agritex. A canal linking Tawona canal to the booster sump station was constructed. A link of the booster station to the main sprinkler system was completed in year 2002. Earlier on in year 2000 Agritex design engineers held discussions with the Mutema farmers over the option of a joint or separate canal and pump station with Tawona. The farmers opted for separate canal and pump station assembly[13]. What was still required was the separate linking of the Mutema canal to the main river pump station separately.

In year 2000 Agritex was doing the detailed designs of the canal, when water law and water sector institutional reforms took place. Their provincial design partner DWD assumed a new name ZINWA, and it became unclear whether they would continue with their roles in design, supervision and maintaining the proposed river pump station for Mutema Irrigation Scheme. One senior technician made it clear that ZINWA had no allocation for any irrigation works in year 2000[14]. The new Department of Irrigation in the Ministry of Rural Resources and Water Development has now taken the leading role in design, operation and maintenance of irrigation schemes in communal lands. Some confusion still exists in the Ministry of Lands and Agriculture especially in the Department in Agricultural Engineering where the irrigation personnel are eager to join the new Department of Irrigation but management seems reluctant to let them transfer.

The shift from borehole to river water would present these farmers with two separate pump stations and ZESA billing points in series is similar to the configuration at the Bonde scheme (see chapter 7), where four booster pumps will initially pump into the same main line before water can be divided between the two blocks. The Tawona farmers next to Mutema have only one pump stage and one bill, and are paying their river pump electricity bills successfully. The use of river water automatically entitles them to state dam water, with its associated water bills being immediately payable. One local EW said *"Zvemabiri matatu ndinoona zvingaremera mafama. Ko hapana here nzira yokuti vachinje kuenda kune zvemigero kana kupombera mutank vozounza nemigero?"* (Three bills might be too heavy for farmers. Is it possible to change to surface irrigation or pumping to a tank then gravitate to the field in canals?).

[12] Although Agritex initiated the meetings they were they were held at the DWD offices. Farmers expect front-line Agritex staff to take an active role in addressing their problems. In this Mutema meeting the DWD was chairing and local government was absent. In either case the farmers were not represented. This pushes the solution further into the civil engineering domain with Agritex playing the role of partner and client. This suggests that the scheme after 35 years is still in the hardware and civil engineering phase as defined by Skogerboe (1998) and Uphoff (1999) see Appendix 1.1.

[13] This implies that two adjacent stations will independently feed separate canals, which will run in parallel for a distance of about 4 km with no distribution. These arrangements are normally associated with gravity intakes. Pumped systems under normal government have tended to focus on common supply canals and installation of control structures. The farmers groups here are in favour of a generic split at the pumps in order to facilitate payment of operation and maintenance cost. This arrangement is very similar to the design of Musikavanhu. Tiffen and Harland (1990) alluded to the need for such separation at Nyanyadzi.

[14] The Catchment manager, a former PWE of DWD, revealed that ZINWA is eager to provide services to Agritex but at a price. Agritex got a copy of the price schedule for different services. According to some local Agritex some ZINWA officials were promising farmers that they were responsible for works to field edge during their campaign for water charges. They claimed that the officials had different messages for the different schemes. A firm commitment of when they would be in a position to design, construct and commission the Mutema pump station was not available.

Farmers' views of the problems and best options

The two local EWs perspective is that Mutema farmers prefer the surface irrigation system. They explained that the farmers are comparing themselves with irrigators in neighbouring Tawona who in their view are doing well. They attribute the success to a surface scheme with river lift pumps only. The EW for block II explained that the farmers had used surface irrigation from the start, their soils are clays and they like surface irrigation. The EW for the sandier block I also explained that the farmers actually want surface irrigation because it would allow them to apply more water which can be stored in the soil. He said the farmers argue that the sprinklers are applying little water and there is no soil storage in case of a pump breakdown. They point out that crops in Tawona survive better because of the soil storage while their crops at Mutema quickly wilt. The farmers are faced with basically two undesirable situations. They are being asked to pay higher than their traditional rivals at Tawona who are using surface irrigation. The Mutema farmers attribute their failure to pay the electricity bills, as now required of them, to the higher magnitude of their bill. When electricity is cut off they experience more severe damage than the Tawona scheme due to less soil water storage as a result of low depth application by sprinklers.

However, they have only one pump running - No.3 (called "the Mutema"), which at its best can supply half their needs. They therefore are already in deficit and face cycles of up to 14 to 17 days even without breakdowns or cuts in electricity. So when they have one of the frequent breakdowns or electricity cuts they experience severe crop damage. In the farmers' view, if they were using surface irrigation they could apply more water at each turn that could buffer them during these deficit periods. The farmers may have a point on the inherent system differences centred on the soil storage. The surface irrigation experience and evidence at Tawona could have been due to the higher system delivery[15]. High water delivery can lead to high soil storage and dilution or leaching of salinity. Even failure to grow beans successfully was attributed to this lack of buffer application by sprinkler systems. So according to the EWs the inherent incapacity and unreliability of the pumping system is not seen by the farmers as the main issue, but rather the application system. There is also a general shift in planting dates from April to May or even June due to electricity cuts as occurred in year 2000 as shown in figure 5.4.1. The summer planting in both 1999 and 2000 was also delayed due to electricity cuts due to non-payment in both cases.

The farmers confirmed that they were convinced by the DWD borehole drillers' assurance of high yields from the new borehole number 5 near number 1. An outspoken farmer told me bluntly that they were not satisfied with the conduct of the Mutare company that did the installation of the pump, and were not confident of the company's ability to install the pump. He also said they were also not confident of Agritex's supervision of the job[16]. I asked him on 14 February 2001 about why their cotton crop was not looking good in spite of a good rainy season and no irrigation delivery breakdowns. The actual problem was lack of confidence in the WDSS that was leading to reduced crop care, attention, input levels and management. This irrigator said "*VaChidenga muri munhu mukuru. Takakuudzai kare kuti tinoda kuti mvura iwande uye ive neassurance. Izvi zvekuramba mobvunza kuti ko marima sei imi musati maita izvi zvichazoita kuti tikutaurirei zvinokushatirisai. Saka ngatinyaranei*

[15] Makadho found the RWS for summer 1990 to be 0.9 and winter 1991 to be 1.23 (Makadho in Rukuni 1994 *op.cit.*). This translates to fairly adequate water delivery for both seasons. Considering that the study took place in the middle of a drought the farmers observations of a relatively better delivery at Tawona have merit.

[16] The farmers' position is further strengthened by the fact that the company folded a year later. Unfortunately for Agritex and me in particular the company official who was responsible for the installation was my former head. The farmers could not understand the contractual arrangements and they obviously were suspicious of me.

nhaika". (Mr Chidenga you are a senior person. We requested you to increase our water supply and reliability. Your continued questioning of our cropping practices is not welcome. If you continue questioning without first addressing our issues we will start being hostile. So lets respect each other). The call for mutual respect in our culture is a polite way of closing a controversial discussion.

I really felt bad in front of my workmates, and the farmers' family and helpers who were harvesting cotton. But the farmer's message was crystal clear. They need increased and reliable water supplies. The boreholes could not be relied on. The Agritex's river plan was too slow. The ZINWA colleagues were just talking not acting. The farmers' observation that it is very difficult to discuss management when water is scarce is in line with observations made by Levine (1980), Keller (1986) and Uphoff *et al* (1990). To appreciate the farmers' and extension workers dilemma one needs to consider the water delivery performance of the Mutema scheme.

5.7 EVOLUTION AND DECLINE THE PRACTICE OF SPRINKLER IRRIGATION AT MUTEMA

The lateral distribution subsystem

Farmers say the Mutema sprinkler system worked well until the mid 1980s. However there is no documented evidence as there was no deliberate monitoring or evaluation of the WDSS performance at Mutema prior to this study. That the Mutema WDSS outlived similar overhead outfits at Deure and Chibuwe supports the notion that the system was fairly robust until some marked elements of decline started to creep in.

According to the senior water bailiff the general shortage of water is the main cause of the water distribution problem. Leakages significantly influence water distribution[17]. In his view a lot of farmers could still manage to produce a crop on a cycle of 18 days if the system were not leaking. He says that in block I the Mutema borehole No. 3 can easily supply water to 15 laterals each with 15 sprinklers. Currently they can only manage to use 10 laterals of 15 sprinklers or less each due to leakages. Some of the numerous leakage points are shown in figure 5.2.1. The leakages are mainly found on the hydrants, the aluminium pipes and the sprinkler couplings. A typical leaking hydrant is shown in photo 5.7.1.

Photo 5.7.1. A typical leaking hydrant in block 11 Mutema

[17]The dedicated senior water bailiff is always in the field. He rides around on his personal motorbike.

Farmers open and close hydrants while the pumps are running resulting in damage to the hydrants[18]. Some farmers charged that they were paying maintenance fees to Agritex who were not doing enough. They believe that Agritex personnel are not competent enough to repair all the leaks in the field distribution systems. They are not convinced that repairs to the distribution leakages can significantly improve the water delivery. They are not willing to listen to explanations from the water bailiffs on the effects of components like hydrant valve seals on water loss. Some typically prefer to fix leaks using stones as shown in photo 5.7.2.

Photo 5.7.2. The left farmer has a stone to fix the pipeline leakage

When new material was bought to replace old equipment, farmers expected to be supplied with exactly the same material as per original design. The farmers were not involved in the planning and procurement process. They could not understand why new material e.g. aluminium replaced galvanised iron. Table 5.7.1 summarises the scenario of the lateral and riser changes as viewed by the farmers.

In using the new equipment leaks become more common as farmers could not use their old practices on the new pipes. The old GI pipes had ball and socket couplings. They had a large circular groove, which they could fill with their own cut rubber, or plastic rolled into a gasket-like roll, or tyres cut up into suitable gaskets, and sometimes grass rolled in plastic. The old coupling could take all this as all it required was material that could fill the groove and the pressure provides the sealing. The farmers could hammer the pipe end to ensure tight fit of filling material as shown in photo 5.7.3.

It has not been easy for the farmers to seal leaks on aluminium pipes. Aluminium pipes have a flatter and more specific groove. The farmers cannot fit local material into the groove to provide the pressure sealing. Until now, even though another set of aluminium pipes was bought in 1996, the farmers are still in favour of the old galvanised iron. Some farmers acting on behalf of others approached an indigenous irrigation company dealing in irrigation pipes and couplings to rehabilitate their old pipes[19]. The owner of the company proposed joining the

[18] At the end hydrant of the southern line in block 1 I had a discussion in October 2000 with a male farmer, his children and the neighbouring female farmer. The male farmer is an outspoken critic of Agritex. He was convinced that the operational borehole number 3 alone could never be able to fully pressurise 15 sprinklers per lateral, in block 1 contrary to what the senior water bailiff was explaining.

[19] The old pipes from the 1970s have not been taken away and most of them are still heaped in the yard next to the former manager or supervisor's and now team leader's house. This stock of pipes acts as a reminder to farmers who have refused to accept aluminium pipes.

new coupling to the body of the galvanised pipe using trinepon (a kind of glue). Samples are displayed at the office. Unfortunately the farmers who are promoting this do not seem to be putting their money to support the venture. Most of the registered plotholders are old first generation irrigators who are familiar and still prefer the old original equipment. They are not willing to leave decision making to the new generation farmers. Therefore the adoption of new technology to replace old pipes is going to be a slow and painful process. Enquiries with irrigation companies in 1996 including the original supplier, Mobile Electric, suggest that it is not possible to use galvanised iron for laterals any more. The cost of iron had increased so much. One would have to make a special order. Most commercial and a few smallholder farmers are now using aluminium laterals[20].

Table 5.7.1. Experience with the use of different laterals and risers from 1970 to 2000 at Mutema.

DESCRIPTIONS	OLD LATERALS	NEW LATERALS
Material and Coupling	Galvanised iron (75mm diameter) 1970Ball and socket coupling	Aluminium (50mm diameter) 1987 Aluminium (75mm diameter) 1996
Views on Durability	Withstand high variation pressure (structure and strength)	Burst under high variation pressure blow out and seam line failure
	Not damaged by cattle hooves	Easily damaged
	Withstands wheel load eg empty cart	Easily damaged
	Trouble free operation	Poor design
Practice-coping With coupling leakages	Initially managing agency supplied rubber seals then stopped farmers then used grass and plastic in joints as rubber seals	Grass cannot stop leaks. Plastics not usable. Have to buy individual rubber gaskets at Farm and City in Chipangayi
Repair to lateral Body	Repaired by welding in gas on site By management agency	Have to take to ARDA estate Workshops at farmer's cost
Farmers' Perceived Solution	To retain GI body and have hydrant and joints modernized, already taken own negotiations for rehabilitation	Visit ARDA to check – believe some laterals stolen by ARDA and settler workers to replace losses
	OLD RISERS	**NEW RISERS**
Material and Coupling	GI riser welded on GI lateral	Aluminium tied to lateral
Farmers' views	Double–clip problem free	Single clip ejected by pressure, lateral and riser tied together with wire or string
Coping with leakages	Filling socket with grass, rubber, Plastic, banana leaves etc effective	Tie outside with string not effective, grass in groove not effective
Storage practice	Risers used to hold pipe stakes together	Not strong
Source: Field observation		

[20] The situation changed slightly in May 2002 as shortage of foreign currency forced the price of aluminium to go up significantly. There are now companies that are offering GI pipes instead of aluminium. Unfortunately the Mutema scheme has not been revisited because of the workload of rehabilitation in systems affected by the land reform programme.

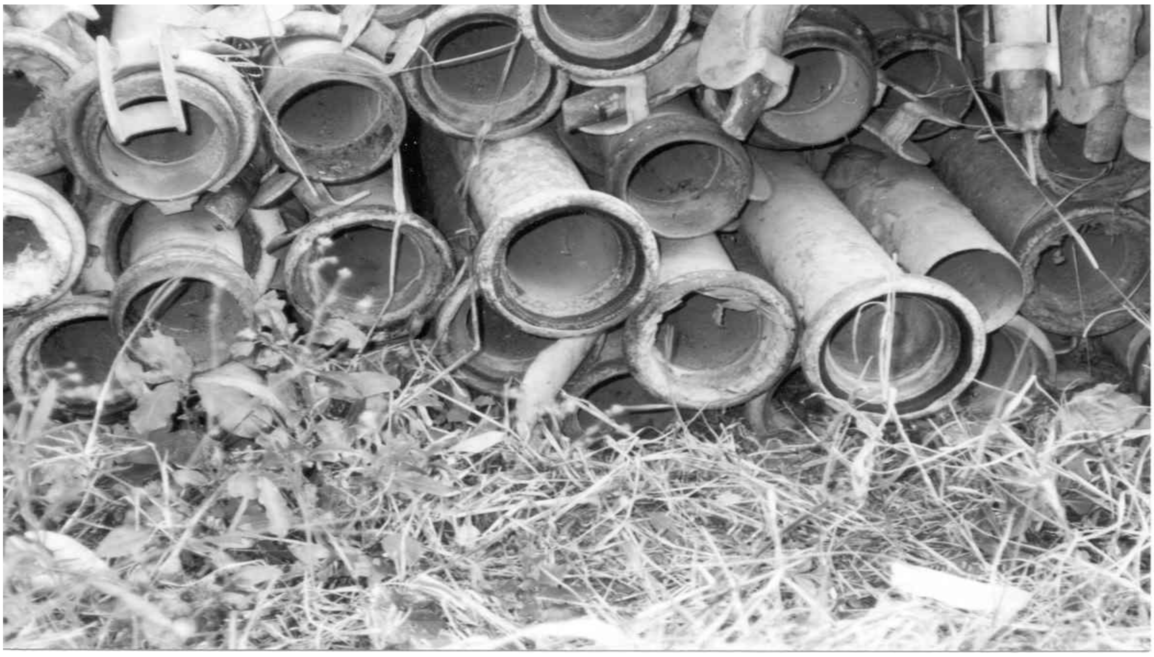

Photo 5.7.3 Local plastic and rubber used to seal GI couplings for the old pipes

Lateral movement

The whole network distribution system supplied water to a total of 52 hydrants each with 15 sprinklers per lateral on a 12 x 18m spacing. The Mutema irrigation system has conventional "commercial" type laterals taking off from hydrants. They were originally designed for a "normal monoculture-one proprietor" system of operation and maintenance. Most farmers share laterals across plots. A single lateral spans plots belonging to different plotholders. During operation the sprinklers on a lateral will be shared by two plotholders who may be irrigating different crops. Women change the laterals in most plots. They may take turns to move the lateral in their fields. Laterals are normally changed once around noon and at the end of day or early in the morning. The afternoon shift normally takes place between 1100 and 1200 hours.

During changeover the pumps are switched off and farmers disconnect the pipes starting, from hydrants to the end or vice versa. They then uncouple the pipes before they move them to the next position. Sometimes they just lift some pipe lengths without uncoupling, a traditional problem with lateral move systems. Some hold them individually as recommended. Others try to carry as many as possible. In a number of cases there are at least two to three people to change pipes. This is normally done to enable them to complete in time and avoid delaying others. The water bailiffs traditionally check that the farmers have changed and aligned the pipes properly. The farmers attempt to clean the pipes of grit before coupling them. The grit leads to clogging or excessive wear of sprinkler nozzles. In practice some farmers use couch grass as seals to replace worn out rubber gaskets. Some buy rubber gaskets from the local farm and city at Chipangayi. However these gaskets are individually owned and used. The farmer brings rubber gaskets to the field in her arm like bangles and puts them into the lateral when it is her/his irrigation turn. After irrigating her/his plot the gaskets are taken back home. The farmers' perception is that if one does not have the gaskets then the amount of water applied to their plot would be substantially reduced by the leakages. This would mean that they would have stress in their crop before the next irrigation turn.

After completing the changeover, the farmers check for leakages and tie the outside with grass/rubber/banana leaves to reduce leakages in coupling joints. The laterals are checked for the turning of sprinklers. To farmers, the most important criterion of good performance is that the sprinkler is turning. The actual discharge or sprinkler turning rate are not considered. The water bailiffs are expected to ensure that all laterals have been changed before requesting the pump attendant to resume pumping[21]. In most cases the pump is just switched off for 1 hour to allow pipe changing. A local telephone line connection between the Agritex office and the boreholes was used to communicate and pass on irrigation requests. This line has now been down for a number of years. The water bailiffs have to walk or cycle to the boreholes for the pumps to be switched on and off. The senior water bailiff normally rides to the borehole on his motorbike[22].

The redesign and rehabilitation of 1987 provided for smaller aluminium laterals and sprinklers. The scheme was then requested to use 12m x 12m spacing to increase uniformity of application[23]. This would also increase unit precipitation to compensate for the smaller discharge if the new sprinklers. This was accompanied by supplying more laterals. However, the hydrants were not increased. In the second rehabilitation of 1996 the aluminium laterals were reverted to the large 75 mm (3”). A spacing of 12m x 18m was recommended, reversing the 1987 proposal. This was an attempt to restore the old order of using bigger laterals of higher capacity. Farmers reduced this further to 12m x 15m by simply removing 3m length of header line in the process of coupling lateral lines. An attempt was made to divide the scheme into discrete blocks, with an isolation valve and water meter. It was suggested in the design report that each sub-block with a valve and water meter would operate as a unit. This would constitute 6 hydrants and 4 laterals serving an area of about 20,4 ha. This was an attempt to create direct equipment and user linkages aimed at fostering group care units.

The proposals were approved by Agritex and implemented on the ground, but the farmers and water bailiffs have not adopted this in practice. The lateral movement and users and sharing arrangements remained as before. The water meters were never used. In fact, as discussed earlier they were forgotten to the extent that this study could not verify their existence. The water bailiffs also never referred to them in the data collection discussions. It was only when bulk meters for the two separate blocks were installed, that the resident engineer was informed of the existence of the earlier installed smaller meters, some of which are working but never had consumption recorded. Farmers, local extension staff and water bailiffs could have deliberately ignored the water meters, as they are associated with water charges (see also Mpudzi chapter 8).

The practice of using half laterals was quite common according to the senior water bailiff. It was used both before and after the redesign. Two halves would be equivalent to a full lateral although they could be operating in different locations. When the senior water bailiff determines the number of operating laterals these half-laterals are combined. This practice makes the system flexible. This type of flexibility was however not designed for. What seems important to farmers is the ability to irrigate with a lateral that covers their field alone. They care about the lateral only during its use in their specific plot, and are prepared to buy and retain personal gaskets for reducing leakage only during irrigation of their own plots.

[21] I observed some ladies changing laterals and the water bailiff never came. The ladies said this was unusual.

[22] The senior water bailiff is also a local farmer. He bought the motorbike from one of the extension agents who had been allocated a motorbike on another extension programme. People believe it is his good farming that enabled him to buy a bike.

[23] The use of smaller units was a compromise between conversion to draghose and retaining the old “commercial layout and operation”. This was discussed between the farmers and irrigation specialists.

Lateral repair practice

The water bailiffs stated that farmers are responsible for replacement of damaged laterals especially those damaged by cattle or scotch carts[24]. They claimed that previously they got them repaired at ARDA[25]. They also claimed that a number of farmers have replaced worn out or damaged laterals, although there are no records or evidence to support this. There is however a heap of laterals that they claim were damaged by poor design. They strongly believe that the system has excess pressure and some pipes were poorly manufactured. On inspecting the laterals together we found that some laterals only required some nuts and bolts to be tightened using ordinary spanners and yet they were condemned. The water bailiffs and workshop attendants have no spanners even to do this: although they believe these should be supplied the Agritex hierarchy, there is no evidence of requests.

The workshop attendants have not attempted to run the repair workshop on their own and they have never been trained to do this. They are requesting gas bottles to enable them to weld. The farmers had taken the initiative to look for a company that could rehabilitate the old pipes for them[26]. The new project engineer followed the gas bottle procurement issue and got negative results[27]. The original on-scheme repair of GI pipes is no longer supported by the local industry due to the limited scale of business. This is not clear to the local extension staff and farmers.

The sprinkler water application subsystem

The experiences and perceptions described with respect to lateral changes, also obtained with sprinkler changes, and are summarised in table 5.7.2. A smaller common sprinkler replaced the larger original sprinkler as a way of standardizing and introducing a product that is readily available on the market. The farmers' perception was that the new system was poorly designed, and they felt vindicated when aluminium pipes were seen bursting (something very rare for galvanised pipes). The 4 mm nozzle sprinkler could not discharge the amount that the farmers were used to. They farmers, workshop attendants and water bailiffs decided to enlarge the nozzle by drilling the hole with a large diameter bit. They also increased tension by replacing the new "soft"" springs with the old ones.

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[24] Most of the water bailiffs are also local farmers. This situation is also observed at Deure and Chakowa. It seems to have been practice in most old schemes to employ locals. The DWD pump operators recruitment seem to differ from this practice.

[25] The repair equipment at ARDA is now itself beyond repair. It stopped functioning in the late 1990s. ARDA now relies on the indigenous company that was trying to extend its repair coverage to the Mutema farmers (personal communication).

[26] The owner of a Harare indigenous company who had discussed the lateral replacement issue with farmers explained that they need the gas to braze the old galvanized iron laterals. He explained that the advantage of galvanized iron against aluminium for smallholders is that you can repair leaks caused by cattle or ploughs simply by brazing.

[27] These were required for cutting and welding during the repair of the main line damaged by cyclone Eline. From the time and effort and bureaucratic purchasing complexity that the engineer went through it became clear that the water bailiffs' initial recommendation that high ranking officers to be involved in gas procurement was correct. This engineer failed to secure the gas bottles after going from office to office. The gas suppliers said the Mutema scheme used to have a contract with them. They were not eager to renew it because the gas was hardly used and therefore the stock of gas bottles was not effectively allocated.

Table 5.7.2: Attributes of the different sprinklers supplied to Mutema

Type / Name	1970	1987	1996
Nozzle size (mm)	6x3	4	4
Discharge (m^3/h)		0.68	0.68
Spacing recommended	12 x 18	12 x 12	12 x 18
Diameter of throw (m)		25	25
Design operating Pressure(kPa)	350	350	350
Farmers view and action	good	Too small nozzle, spring easily breaks	Too small nozzle
Water bailiff's view and action	good	Drill and enlarge nozzle, change to use Lancer springs	Reduce spacing to 12x15
Availability on market	Available (not common)	Readily available	Readily available
Source: Field observation			

There are no records or reports of lost galvanised iron laterals. However as for sprinklers there are reports of farmers stealing from each other. The original irrigation agency devised a mechanism of coding and marking sprinklers. Each sprinkler was coded and a farmer or water bailiff could identify its origin at any time. A number of sprinklers with these codes engraved on the sprinkler body are found among the old equipment at the scheme. One was engraved SEKAI L16. On checking the farmers said that such a sprinkler belonged to a group that starts in SEKAI's plot and it is the 6th sprinkler on the 1st lateral. Farmers and water bailiffs strongly believe that the coding guarded against theft. Farmers confirmed that there still is a lot of internal theft of sprinklers and lamented having to leave them in the field overnight. Some farmers actually take the sprinklers home. The old irrigation managers ensured that farmers who lost sprinklers replaced them, otherwise they would be sanctioned by being denied water. Farmers today cherish this type of sanctioning. They said that a lot of unemployed youth were hired to steal rubber gaskets and sprinklers from one plot to another. At the time of research, any new sprinklers were immediately stolen. They said people could lose a whole line of pipes and sprinklers over night.

Sprinkler replacement practice

There is currently an assortment of sprinklers operating on a lateral at any one time. Some are larger diameter nozzles and others are small. Some have double nozzle. Most are rotating impact type although there are some rocker arm sprinklers. The latter are being used although rehabilitation programmes have never supplied this type of sprinkler. A typical rocker sprinkler is shown in photo 5.7.4.

Farmers and water bailiffs claim that farmers are replacing sprinklers on their own. In fact the farmers buy any sprinkler they find on offer at the local Farm and City shop (previously the Farmers Cooperative) at Chipangayi, or in Chipinge. There is no clear acknowledgement and appreciation that government supplied replacement sprinklers in 1987 and 1996. Most of these replacement sprinklers are giving problems with clogging. Some do not turn. The local extension staff attributes the presence of different sprinkler types to the requirement that farmers replace those damaged and missing. One former supervisor introduced a system whereby the farmer would bring to him proof of purchase of a new sprinkler e.g. by means of receipt. Only then could the farmer take the sprinkler to the EW and WB to get it fitted and checked for conformity. However farmers levelled many complaints against him to the district office, resulting in him being transferred to dryland work. Currently a receipt is not required, and sprinkler control is the job of the supervisor – but there is no longer a supervisor post in Agritex. A team leader role was introduced in year 2000 at Mutema.

Photo 5.7.4 A typical rocker sprinkler with a stone to enhance operation at Mutema

According to the local extension staff the supervisor's action was necessitated by the need for good neighbourliness with the ARDA and Middle Save settler schemes that have 8000 ha under sprinklers. The authorities there suspected Mutema farmers were "getting access" to their sprinklers. Mutema farmers have been quick to point the blame the other way. They say that the settlers and ARDA penalise their workers if pipes and sprinklers go missing or malfunction. For fear of losing hard earned money these workers "find access" to Mutema sprinklers. Both these commercial outfits and Mutema tend to have similar varieties of sprinklers operating per lateral line. One cannot determine the dominant direction of sprinkler movement between Mutema and the estates at a glance.

The number of sprinklers required per lateral at Mutema has remained rigidly fixed at 15. No variation has been made to the lateral length and spacing between sprinklers along the lateral. The variations to date have focussed on the lateral spacing.

Organisation of distribution and application O & M at Mutema

Women irrigators dominate in actual pipe changing activities. They pointed out that one of their problems was that children are sometimes sent to irrigate on their own without older people. Farmers are sometimes not sure of whom they share their hydrants and laterals with. A farmer simply comes to irrigate when it is his/her turn as per the water bailiff's records. A plot owner can rent or lease a plot at will (though illegally), thus changing the composition of actual irrigators. There is no organisation on the use of the shared distribution and application equipment. The farmers operate individually, and rely on Agritex water bailiffs to co-ordinate any activity. Agritex is expected to do all repair work to the distribution system. Farmers always refer to the old days when repairs were done promptly. They were not aware of any new valves and water meters put in to help transform the scheme into discreet units that could operate separately. On asking if they were prepared to take care of equipment they shared in small groups, they quickly asked what the role of Agritex would be. In the farmers' view they pay maintenance fees to Agritex that has staff with responsibilities for equipment care. The general view held by farmers at Mutema is that Agritex provides a service that farmers pay for. On enquiring whether they felt the $145/ha was sufficient they said there was nothing they could do with such a poor water supply.

Plot irrigation performance - Uniformity

The senior water bailiff determines the pressure adequacy by visual observation from experience. A catch can determination of the system performance on some farmers' plots gave the results shown in table 5.7.3. The plots were selected in the sandy block 1 that was operating after the cyclone had damaged the supply line to block 11 as shown in figure 5.2.1. Plots were selected close, in the middle and furthest from the pumps. It was not possible to find three consecutive sprinklers operating well in the ideal positions 5 to 10 from the hydrant out of the 15-sprinkler laterals. The selected sprinklers that were operating "reasonably well" that is turning at reasonable rates and distributing water reasonably with minimum leakages at the sprinklers and their relative positions on the laterals are given in table 5.7.3. The sprinklers are all operating at pressures well below the recommended pressures of 350 kPa as detailed in chapter 8. The resulting Christiansen's uniformity values are classified as poor according to Watermeyer's classification of 1990 (Watermeyer 1990). The main cause of poor uniformity is low pressure due to: leakages in the main line at hydrants, lateral gaskets and the riser lateral couplings; and sprinkler nozzle wear and at some valves.

The water bailiffs seem to be experienced enough to determine the number of laterals and sprinklers to work under a certain level of system leakages. A few farmers at times use 16 instead of the recommended 15 sprinklers as way of enhancing uniformity and increasing precipitation especially at the lateral ends, but this leads to runoff in these areas. The water bailiffs constantly refer to the actual number of sprinklers operating at any one time. One major problem is clogging, from a variety of sources: sand, grass, and even pieces of cloth coming from the attempts to substitute rubber gaskets with "local material". Clogging of nozzles from use of saline water was evident in the old sprinklers.

Table 5.7.3 Sprinkler performance at Mutema irrigation scheme

Plot number	Christiansen's uniformity coefficient (CU %)	Sprinkler Operating Pressure (kPa)	Position on lateral from hydrant	Wind speed (km/h)
A30	61.93	275	2,3 and 5	10
A40	6.93	170	11,12 and 13	11
A59	60.7	200	3,4 and 5	10
Source: Field measurements				

The general scheduling currently is not crop based and the deficit on the water supply makes it difficult to debate this. Generally the rule is "to turn the water round as early as the system can allow equitably". There seems to be no facility for individual water requirements to be considered. The objective of adopting overhead irrigation with pumped borehole supply was to mange a scarce water resource using inputs from expensive resources like the pipeline distribution and sprinkler application subsystems as well as energy. To get optimum results a high level of management is required. The current problems indicate that this lacking. The net result is that an expensive operation and maintenance system is running only to introduce salinity to the soils.

5.8 DISCUSSION AND CONCLUSIONS

Mutema was conceived and initiated as a simple gravity run-of-river system consistent with other first generation schemes Deure and Chakowa of the 1930s. The need to both expand the scheme and stabilise the water supply resulted in the adoption of borehole pumping. To further enhance the water management and irrigate marginal sandy soils a pressurised overhead WDSS was introduced. Therefore the scheme made an early jump and has retained two trajectory steps that is pumped supply and pressurised distribution and overhead application. The scheme was however never monitored and evaluated to test the conformity of the system to the original objectives. It operated "well" for almost 15 years and started to decline. This study made some observations and revelations that call for an urgent need to identify long term leverages to sustain the Mutema scheme.

Finding leverage to the enduring solutions to the Mutema sprinkler irrigation scheme requires revisiting the choices of technology and operation and maintenance structures envisaged at the original design stage.

The choice of the borewell water source was made in view of the inadequacy of the Tanganda run-of-river flow as well as the apparent lack of suitable site for a storage reservoir upstream of the scheme. It may even have been an emergency. Borewells were also a first choice at Deure but soon replaced by the more enduring construction of the Ruti dam and improved surface supply: such a solution may still be open in the future in Mutema. A similar solution is possible for Mutema and its implementation is still open to the dam engineers who fortunately have not ruled it off. The choice of the sprinkler water delivery subsystem was informed by the belief that pressured systems have a higher capability to distribute and apply limited and operationally expensive borewell water in the marginal sandy soils of block 1. Manzungu (1999) reports a similar debate at Chibuwe. Unfortunately at Mutema designers were also confronted with salinity problems of the borehole water presenting yet another unforeseen limitation. They tried to counter this by adopting a looped design with an operational requirement that the Mutema borewells are operated as a closed system. Low salinity borewells were required to dilute high salinity wells during operation. This however assumed that all the wells would operate with equal reliability and durability. Only borehole no. 3 has lived up to this. The continued use of this one well, combined with longer irrigation intervals, actually means the increasing salinisation of the soils and depressed yields. Salinisation has led to farmers openly discourage each other from growing beans. They already accept that there the tolerance of maize may also be facing its limits due the significant yield reductions they have observed. The solution to the salinity problem never involved any detailed leaching requirement calculations and monitoring for sustainability. The situation is again operating as another quick fix solution that has been left to stay on forever.

When the number of borewells operating or the discharge falls below the design threshold due to breakdowns or leakages, the system cannot continue to channel flow to all open areas. This has resulted in operating pressures below those recommended by design, leading to poor application uniformity. Water bailiffs at Mutema use their experience to reduce the number of laterals, to raise the system pressure to a point where the sprinklers start turning. These sprinkler-turning-pressures as given in table 5.7.3 are unfortunately too low for good uniformity of application. The water bailiffs understand the need to reduce number of sprinklers to increase pressure and uniformity. What they cannot understand or make adjustments to is the salinity level that is tied to the Mutema closed design. The second limitation is that they cannot influence the repair of both the water mobilisation and water distribution and application subsystems to conform to the design requirements. Therefore this one functional MSSS leverage has capacity limitations.

The government institutions that are responsible for the O&M of the distribution and application subsystem have failed at the higher institutional levels to sustain support to the local members in backstopping their efforts. There has been a lack of planning, supervision and backup of the efforts of the senior water bailiffs and his team. The workshop has been allowed to run down and no spares are available. Local staff members have not been kept abreast with technological changes. This has made it difficult for them to be instrumental in supporting farmers to adapt to new technologies like aluminium and small sprinklers. Thus a rift has been allowed to develop that is filled with mistrust, and suspicions.

Farmers at Mutema are not involved in the discharge or pressure manipulations and adjustments. They were assumed to be passive recipients of technological interventions at design stage. This situation has been rigidly maintained at Mutema with both government and farmers accepting it until the financing shortfalls became unbearable. The main problems with the Mutema distribution and application subsystem relate to leakages emanating from hydrants, lateral-lateral couplings, lateral-to-riser couplings and poor repair or use of incorrect sprinklers and sprinkler spares. Farmers still expect Agritex to provide all the repair and maintenance work as at the beginning. Agritex has tried to rehabilitate the scheme but unfortunately changed equipment. There seems to be very little coordination and training between farmers and agency staff that informs farmers of the need to adopt new equipment. Farmers and local staff are simply supplied with new equipment and left to discover how to use it. This has created tension and hardened farmers who then try to restore the original infrastructure. The local Agritex (now AREX) staff and the water bailiff can cope with pressure related problems if adequate support and training in running the workshop is provided. However the issue of salinity also needs attention at the right technical and management level. There is no evidence that the local staff members will be able to manage salinity at Mutema without direct government involvement. This issue needs attention before or during handover of management.

It is not possible to examine salinity without considering drainage. The drainage network for Mutema was probably well developed and adequate when the system was first constructed as a surface scheme using fresh water. The scheme has an elaborate system of storm drains that function better that the Deure, Chakowa and Bonde. These storm drains take most of the water from the two mountains that border the north of the scheme. The central drainage of the scheme shows that it used to have an elaborate main and secondary drainage that brought water to the centre drains running along the main road through the offices draining into the Tanganda. This drainage network is, however, over-grown with grass, and a lot of drain crossings make it impossible for the drain to function well anymore. The drains were probably neglected when the sprinkler system was put in place, on the theory that it was likely to be more efficient and therefore the need for drainage would fall away. However, the use of saline borehole water did add to the need for drainage. The future use of the Save River water when the river lift pumps start working could enable some desalinisation to take place, but only if adequate drainage is to be provided. However since the existing borehole use will continue, soil salinity will always need checking. The need for drainage care was further emphasised when Cyclone Eline floods forced the Tanganda River to use the main drain after backwater from the storm drain spilled over it. The lower level land of Block II clay has been “reclaimed” by the Tanganda River, such that it now flows over the original location of the sub-main pipeline that was supplying this block. There is a need to reopen and maintain drainage works at Mutema.

The use of boreholes with saline water is a design issue that is easily overlooked. The focus on physical water delivery security and reliability tends to overshadow the need for salinity management that informed the closed system design. The current problematic therefore calls for a continued attention to the chemistry of the soils that the neglect has created.

In order to leverage the WDSS system to deliver, distribute and apply water as per design objectives, the different layers in the MSSS need to perform as envisaged at project creation.

The choice of the sophisticated WDSS itself was informed by the limitations of the water source capacity and reliability as well as the marginal soils of block 1. Planners and designers were aware at that time of the high government and farmer leverage requirements of the MSSS in order to sustain a sprinkler WDSS. These were initially provided at Mutema but have since been withdrawn. The system was clearly designed to manage marginal water and soil conditions and not to empower communities. The government institutions responsible for the borewell operation and maintenance need to be well resourced, capacitated, knowledgeable, motivated and have sufficient incentives and sanctions to ensure a reliable water supply is available. Failure as noted at Mutema launched the whole intervention into a non-sustainable cycle. The short-term leverage therefore lies in ensuring that the MSSS at Mutema is adequately and appropriately provided for, to ensure the sustainability of the WDSS chosen to deliver a scarce resource of poor quality to a simple community largely growing livelihood crops. Goals related to irrigation management transfer require a re-focus and re-definition of the objectives to ensure congruency - and may even necessitate continued government support rather than turn over.

The long-term leverage lies in first providing a stable water source with a robust water delivery at Mutema. A dam on the Tanganda or linking up to the proposed Ruti-Osborne-Rusape canal supply sub-systems are two options worth considering. There is a clear need to narrow the technology-management gap between farmers, local staff and agency staff, and irrigation equipment manufacturers and suppliers. This can be done through on-going exposure to equipment, through visits to show exhibitions and training. For sustainability, the irrigation technology transfer should also be linked to a gradual irrigation management transfer program where farmers eventually take charge of O&M.

The long term leverage lies in building capacity of farmers and local staff to provide O&M of the sophisticated infrastructure. This involves government investing in training the farmers and technical support staff in the use of the infrastructure and acquiring and managing the necessary financial resources. This will enable them to subcontract, supervise and pay service providers in future.

In cultures where pressurised systems have been adopted to supply water to multiple users, for example in Israel, government agencies, or other institutions are accountable to government-run water delivery subsystems. Farmers are then supplied water at shared or individual outlets and charged on the volume delivered. This puts the maintenance aspect outside the individual farmers or their local institutions. There is need to identify smallholder schemes outside Zimbabwe where maintenance has been successfully done at farmer level, in order to draw lessons and start meaningful engagement of the Mutema farmers. Alternatively a policy decision needs to be taken to recover maintenance costs for the pressurised systems at rates consistent with their maintenance requirements. That is where the other leverage could lie. The maintenance of sophisticated equipment directly by communities needs to be illustrated by clear examples preferably in Africa

However, the experiences gained in use of boreholes and sprinklers by smallholders at Mutema should be recognised in future, as an experience of the use of conventional lateral move sprinkler systems. The fact that only Mutema has been converted, retained and sustained to date means that it has more resilience than some other trials. The Chibuwe block E had a sprinkler system for only seven years and got converted to surface irrigation. The Deure block D II had a sprinkler system from 1970 to around 1988 and almost got converted to surface irrigation until it got a completely new design and hardware.

This study highlights the problems mentioned for irrigation development in Africa. The lack of knowledge and experience both in government and farmers are evident (Moris 1988; Speelman 1990). There was no specific attempt to monitor the scheme performance. No information on the aquifer was acquired during the borehole operation period. What should have been a technological review and upgrading for borehole pump units proved in reality another leap into the dark. The new retreat into the common river pumps seems to be more of a response to farmers' pressures and loss of patience than a programmed improvement strategy.

If the original intention of developing the Mutema overhead sprinkler scheme was to pilot the use of high technology and enhance water control then its current management level is likely to impact negatively impact on the appeal of the technology to users. The question is whether the visible neglect is restricted to this scheme alone or it is a systematic manifestation that requires attention to the national alignment of principles and practice. It can only be hoped that the concept of farmer management in the new overhead schemes is not doing away with terotechnology. Citing the situation in the Gezira system of Sudan, Tiffen observes a gap between scheme design and the quality of men available to do the job of management (Tiffen pp 66, 69 in Blackie 1984). More generally for Africa, Tiffen observes a scarcity of staff of high calibre to do difficult jobs and recommends that they should therefore be allocated minimum tasks over a large area and delegate as much as possible to farmers. The questions are whether this is effective in an overhead scheme like Mutema, and what role may still remain for external technical support and how to organise and finance this. There is a need to train and support farmers in administration, legal and financial management in Mutema. The farmers have good experience with their tomato contracts. They have already tried to rehabilitate the old pipes using their experience and structures. The strategic questions are how to build on this capacity, and how to reform operation and maintenance support, to restore terotechnology in Mutema.

6 MUSIKAVANHU: PUMPING INTO A PROPORTIONAL DISTRIBUTION SYSTEM

6.1 INTRODUCTION

The Musikavanhu irrigation scheme development story dates back to the 1940s when the Rhodesian government also hatched the neighbouring Chibuwe irrigation scheme development plan. The original objective was to divert water by gravity from the Save River to irrigate as much land as possible between the Save River and the Dakate pan. The scheme was rationalised later and planned areas cut off due to water shortages. Since independence a number of plans and designs were considered for the Musikavanhu scheme development. Eventually, a borehole supply surface irrigation system was chosen with hydraulically independent blocks supplying hydraulically linked groups with fayoum weir divisions on a main canal decreasing in size. The group members share the lead stream by rotation. The system was designed to allow both proportional division of flow and measurement that should in theory provide for equity and manageability. Musikavanhu was also conceived, designed, implemented and started operating as the first farmer managed irrigation scheme (FMIS) with groundwater supply. The present Musikavanhu scheme, planned for 967 hectares, lies geographically north and south of the Chibuwe irrigation scheme.

The scheme is a unique combination of rare technology configurations and local management. While the technology appears to return to surface irrigation application methods, its design and therefore system operation are fundamentally different from the both the Chakowa and Deure systems discussed in chapter 3 and 4. The Chakowa system represents an older design approach with low flexibility that was appropriate for an authoritarian management system. The Deure design offers more distribution flexibility due to capacity of the distribution canal that allows cross block sharing of flow. Neither needs expensive energy to pump water into the system, as at Musikavanhu.

The common thread that ran through the different technological options was the need for the project. An Italian Technosynesis report of 1986 first presented feasibility studies of the present scheme - with groundwater supply and either piped sprinkler application or canal surface application, with night storage dams in both cases. An off-river pumped canal system was also considered. Pilot boreholes were drilled and tested for yield and quality to support this study. A 1990 Sir Alexander Gibb and Partners review report did not favour the groundwater option[1]. Funds became available for development coincidentally after the 1991/92-drought period. An implementation team was immediately put together and its priority question was to select a system or technological configuration for development[2]. Consultations and studies were done and a system selected. Many government officials acknowledge the influence of the performance of the groundwater-based Mutema scheme during the 1991/92-drought period in their choice of the water abstraction technology at Musikavanhu.

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[1] Instead they recommended that off river pump stations be developed to supply main canals from which users would operate small pumps for surface application. This system has been used in Egypt in recent years. To avoid problems of founding structures on loose foundations they proposed a complicated gantry system designed to enable pumps to access water from the river at low and high flow without the danger of flooding.

[2] This team comprised a reputed consultant from the developed world and a number of Agritex senior and junior personnel. A senior irrigation planner in Agritex at that time had served less than six years in irrigation.

This chapter first looks at the water supply of the scheme from the groundwater to the pumping capacity. It then considers the water distribution attributes before examining the cropping and other management support capacity that is mainly provided by the farmers. The actual practice of operating and caring for the water supply system is then examined, together with water distribution practices. The study shows that pumping into a proportional distribution system creates problems of dominance of control as farmers' concern over power costs tend to over-ride other considerations. A look at possible leverages to address the maintenance problematic and other issues concludes the chapter.

6.2 DEVELOPMENT OF AN "EQUITABLE SECURE" WATER SUPPLY

As a modern system supported by foreign assistance, at a time attuned to ideas of participatory design and farmer management, Musikavanhu should have offered many options in stakeholder liaison. In practice, however, the team involved in steering technology choices largely kept the debate a technical exercise between expert stakeholders, with farmers only the target of training for local management. Opportunities were missed to involve local actors in groundwater investigations, and to transfer existing knowledge from the commercial sector into planning for smallholders.

Groundwater investigations and technology choices:
A team was formed to spearhead Musikavanhu development between Agritex officials at HQ and a Dutch consultant group, who in turn enlisted the services of Boehmer, a South African consultant geo-hydrologist. Boehmer laid out borehole design details for the whole of Musikavanhu in a study report of November 1992[3]. This expert team visited all proposed abstraction sites, also with participants drawn from Agritex staff at head- province- and district levels, and the DWD headquarters. They visited the borewells of the RWA, then being drilled in large numbers to augment the commercial Middle Save scheme in periods when Save river water was not available[4]. They visited the Tawona smallholder lift irrigation system, as well as an individual farmer using a bush pump to lift water 18m from an open well to irrigated vegetables. They met with a pump expert from ARDA to discuss the management of the Chisumbanje sand abstraction system. The high profile of the Mutema system during the 1991/92-drought period was also brought into the discussion. Groundwater-based irrigation systems seemed promising, although some problems of sand plugging and screen choices were noted. Although electricity costs had just started rising after having been controlled by government, farmers in the first schemes in Mashonaland East and elsewhere were paying electricity costs and doing well. The Tawona pump station showed simplicity and resilience as a structure on the Save River and the farmers' contribution to desiltation of the intake was appreciated.

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[3] Previous studies noted were by Ministry of Water Development (MWD), Hudson and Wurzel 1963 and the 1984-86 Technosynesis study. The Technosynesis is regarded as the "first large groundwater study of the area for irrigation development in the plain." The study included hydrological mapping by means of well inventory, borehole logs, geo-electrical survey of the area, drilling of 8 test wells, well and aquifer tests, geo-chemical survey, analysis for water quality and determination of groundwater recharge.

[4] This suggests that the middle Save scheme effectively uses borewell water as an emergency supply to augment or supplement river flow, as conjunctive use. This commercial farming sector has not opted for individual supplies of borewell water as a major long-term source of water. Rather they retained the river source as the main supply. This is a different strategy from what Agritex adopted at the two smallholder schemes flanking the Middle Save scheme.

Boehmer observed that there were no records of long-term fluctuations of groundwater level. It was recommended that the project start making regular observations of water levels in boreholes and shallow wells on a weekly base for the duration of the project. Two specific observation wells close to block A and B were to be included in the observation, according to the water management specialist (WMS). The DWD technician who was responsible for these observations passed away some years back and has not been replaced[5].

The water quality study identified two strips of good irrigation water (1) in a one to three km (1-3km) wide strip along Save River and (2) in a 2km wide strip along the eastern boundary of the plain and the mountain. Generally the central part of the flood plain, characterised by the Nyautsa River and Dakate pan, has brackish water unsuitable for irrigation. A study with tritium of the Save River and its adjacent aquifer indicated the Save River playing an important role in groundwater recharge of the strip along it. The Technosynesis study estimated recharge at a rate of 500 l s^{-1}, which could rise to 2000 l s^{-1} if the water table was lowered by about 1.5m by pumping.

A stakeholder consultation meeting was then held in 1993 in Harare and the development team presented the different options and perceived advantages. After a day of presentations and deliberations it was decided to go for boreholes and surface irrigation. The development of the scheme started immediately, but progress subsequently became variable. Block A1 was among the first to be completed in 1995, and was selected for this study. Others were still under construction at that time of this study. Table 6.2.1 gives the final profile of the scheme.

Table 6.2.1 Musikavanhu irrigation scheme profile

Description	**Block A scheme**						**Block B scheme**					
	A1	**A2**	**A3**	**A4**	**A5**	**Sub-total**	**B1**	**B2**	**B3**	**B4**	**B5**	**Sub-total**
Block Size (ha)	72	72	65	72	55	336	92	73	72	72	52	361
Number of farmers	60	60	65	72	55	312	75	60	60	60	52	307
Plot size(ha)	1.2	1.2	1.0	1.0	1.0		1.2	1.2	1.2	1.2	1.0	
Number of boreholes	3	3	3	3	3	15	3	4	4	4	3	18
Source: Agritex records												

Musikavanhu borehole pumps

The South African company designed the borewells and supervised their drilling and development. The scheme water is delivered by pipeline from a set of three or four boreholes to independent units of about 72 ha each as shown in figure 6.2.1 for Block A1. There are no night storage dams at Musikavanhu[6]. An additional borehole was drilled and equipped to act as stand–by for any two or three boreholes of required capacity. Borehole pumps were sized using criteria recommended by the consultant geo-hydrologist which took into account the

[5] The water management specialist WMS refers to a former Agritex irrigation specialist for Manicaland who was retained as team leader of the Musikavanhu farmer-training programme and later joined the SISP program.

[6] Agritex specified against NSD as mitigation against bilharziasis and malaria following the findings and recommendations of the Mushandike irrigation scheme studies (Chimbari *et al* 1991; Thompson *et al* 1996.). However an evaluation carried out ten years at the main study site revealed that farmers were not following the recommended canal water management practices mainly due to adoption of different cropping practices (Chimbari *et al* 2001).

screened area i.e. area with medium to coarse sand and the slotted area and velocity of entrance. As a rule of thumb considering a borehole diameter of 200 mm and 20% slotted area a discharge of 3 l s^{-1} per metre length of slotted area was used.

In order to ensure trouble free operation, and realising that the locally assembled mono pumps could hardly deliver 30 l s^{-1} it was recommended that internationally reputed pumps be purchased. Submersible multistage centrifugal pumps that work well with clean water were selected[7]. With the need to have a uniform brand in order to reduce complications all of the boreholes were equipped with reputable European-manufactured submersible pumps[8].

However there is very little servicing that can be done on the pumps and motors. The company that installed the pumps recently moved its main business to Mozambique. A Bulawayo based group claims to have the capacity to service the pumps[9]. Each pump module used at Musikavanhu now cost between US $ 8000 to US $10000 depending on capacity.

The consultant geo-hydrologist outlined the basic design parameters of a good borehole that should have a life of 25 years or more, especially of packing entrance velocity and pumping rates. They recommended use of PVC screens, although that later proved problematic. Boreholes were recommended to be as close to the Save river as possible, and a minimum distance of 500m apart. Such sitting recommendations may have been best for recharge and transmissivity, but seem problematic in relation to bank erosion. Parts of Chibuwe irrigation system have been washed away, and one Musikavanhu borewell is now only 6m from the river.

They also recommended installation of piezometer tubes to help determine the performance of pumps, detect any clogging of borewells and monitor water levels against over-pumping and any saline intrusion. Those installed in Block A1 are not used, and some were blocked at the time of this study. The actual operating conditions experienced locally seemed not considered. The owner of Humani farm, just across the river, estimated the life of boreholes, as mainly in the region of 5-7 years due to corrosion of screens, use of inferior gravel pack and 'excessive' pumping rates of up to 85 l s^{-1} [10]. The Musikavanhu pumps and motor units were equipped with various protection and safety devices against dry well, current fluctuations etc. In fact the current fluctuation sensors, which were set to European standards, initially proved a nuisance as the normal ZESA grid has inherent fluctuations that led to unnecessary cut-offs. The contractor that installed the pumps got over this hurdle.

Farmers say they were never clear about the time they were expected to start doing their own repairs and maintenance, until the assistance programme closed its doors in 2003. The contractor that installed the borehole pumps came for a last inspection in June 2000 without prior farmers' knowledge. Farmers observed that they visited most wells and took notes. They also informed some farmers that it was their last and final inspection that is the end of the maintenance period under sponsorship of the donor.

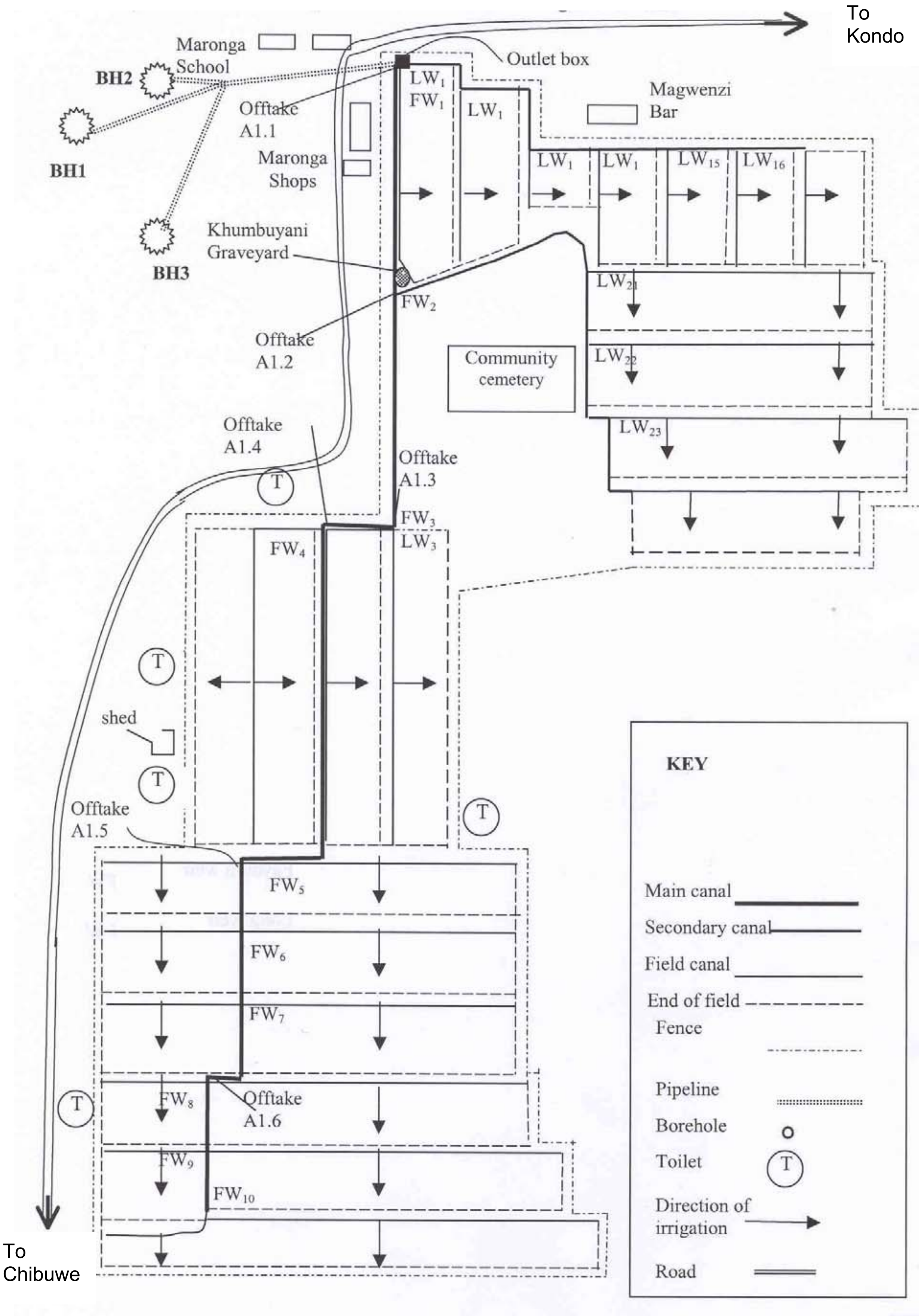
[7] These reputable pumps are reported to give a life of up to 20 years if they work with clean water. One international consultant referred to the pump as the "Rolls Royce" of pumps.

[8] At that time the Zimbabwe government enjoyed excellent relations with the country manufacturing the submersible pump. The high capacity pumps installed at Musikavanhu are not common line items at the company factory and therefore require a special order before manufacture. The issue of foreign currency was never considered an issue due to the good relations that prevailed. Currently the relations have soured and access to spares or required hard (foreign) currency is a nightmare.

[9] A number of dealers can import and install the units on order, and works elsewhere at Mutema and Mutondo revealed that most irrigation companies relied in this firm in Bulawayo. Foreign exchange is the main problem and often has to be sought on the black market. Prices for similar pumps, ordered for the Mutema booster station, quadrupled between the time of tender and delivery in two years due to these fluctuations. The WMS and farmers at Musikavanhu looked in vain for supplied closer to them to service and repair the pumps.

[10] The "Mutema" borewell (BH3) at Mutema, also discharges in this range (see chapter 5).

Fig 6.2.1 Schematic diagram of Musikavanhu A1 Irrigation Scheme



However, there was no formal recognition of this changeover, and "training team" stayed until 2002. Certainly after 2000, farmers started voicing their worries, perhaps for fear of being left with problem situations. Block A1 farmers complained that borehole no. 3 has not worked well since they started irrigating. It only pumps for a few hours then trips and it draws a lot of electricity. Concerned that it was the borewell, the WMS got a different version from pump contractor in use. His view was that the problem was with the pump unit for borehole, not the well. Later the WMS's thinking was to verify this with the DWD's Chief Hydrogeologist.

The basic problem with Musikavanhu borehole development is that during the design and implementation stage of the boreholes in particular there was very little involvement of the local members in Agritex and DWD, or farmers. At one time team members from Agritex completely dissociated themselves from the borehole development exercise. Since borewell development was not part of Agritex's mandate there was a tendency to underestimate the need to understand and appreciate the issues and implications of such processes on sustainability of irrigation schemes. Most of the borehole development correspondence then tended to be between the expatriate members of the team and the consultants who were hired to supervise the borehole drilling, development and testing. The level of understanding of the important concepts relating to boreholes of the frontline extension staff seems to be very low. For enquiries during this study, the local EW referred most questions about borewell design and development to the WMS even though they had documents filed at their station.

The Agro-economic study carried out by JIMAT (2000) also reports that farmers in particular expressed lack of confidence in their ability to take over borehole related issues. However the study was silent on the knowledge base of Agritex or DWD in the aspect of boreholes[11].

One of the objectives of putting together the Musikavanhu development team with senior foreign consultants and full time Agritex personnel attached to the program was that they get in-service training in the various aspects of irrigation planning, design, implementation and management. The training program however lacked details, guidelines and defined outputs to facilitate monitoring and evaluation to enable meaningful reviews to take place. It was only the farmer training component that later got a clear focus as an extension to the development program.

Musikavanhu distribution system design principles

The plan of developing independent units is in line with recommendations made by Tiffen and Harland (1990) after studying water distribution problems at Nyanyadzi. Within each unit water is distributed from the common pipe outlet to six groups by a canal structured at group level. The structuring is done by use of fayoum weirs shown diagrammatically in figure 6.2.1. They consist of a movable downstream sluice gate on the main canal that controls the side weir water level at the off take of a secondary outlet canal. The sluice gate on the secondary outlet canal is in principle an on-off gate that should not be used to regulate flow. The use of fayoum weirs in Zimbabwe started officially at Musikavanhu. They were designed and installed with the assistance of the technical team that assisted Agritex in the implementation of the loan–grant financed project.

[11] The capability of DWD (now ZINWA) at national level to undertake the same type of development of boreholes on its own cannot be doubted. They have been involved in large borehole development work in the Nyamandlovu aquifer for Bulawayo water supply. However the position with respect to the local or provincial office is not clear. However, the local management of borewells, as at Mutema, has shown problems and uncertainties.

Across – group water distribution in theory

Fayoum weirs were mainly chosen to facilitate both proportional division and water measurement. The proportional division meant that the designers could afford to decrease the size of the downstream canals and simultaneously achieve across group equity. Theoretically this requires use of water in all off-takes at any one time. Each change of flow requirement by any group has to be accompanied by a re-setting of the flow to re-establish a new level of proportionality for the new remaining number of users groups. Each block of 72 ha has six (6) proportional off-takes. Each off-take serves 12 ha each with 10 farmers as shown in figure 6.3.4.

These are the ideal operating conditions of fayoum weir and gate operation. This situation works well in gravity systems in humid areas were adequacy of water and drainage is not of paramount importance. Most proportional systems described in literature operate under these humid conditions (Horst 1998, Parajuli 1999, Pradhan 1996). In practice, in Musikavanhu, farmer groups who do not need water close off gates – leading to problems of overtopping canals that lead to significant erosion of the canal banks in the lower groups four, five and six in block A1. When farmers are paying for pumping the irrigation water they close off gates when they no longer need flow in their group. Proportional division systems are not suitable to reacting promptly to human manipulation at all, as this subjects them to tampering and misjudgement. This thus sets the limits of their use in ensuring equitable water distribution (Horst 1998, pp11; Zirebwa 1997, pp82). The canals are designed with minimum structural strength and tend to break and leak without the embankment (Ball cited in Manzungu 1999). The alternative to closing off gates is that farmers in each group continue diverting flow even if they do not need it. The excess water has also contributed to drainage problems for the lower groups.

Horst warns that it is difficult to combine different sensitivity requirements into one structure (Horst 1998, pp 28). The fayoum weir choice was meant to combine proportional division to groups with flow measurement. A downstream supply gate in combination with an upstream side weir outlet gives a sensitivity of 0.5 and 1.5 respectively which is the power of their modular conditions. The resultant hydraulic behaviour of the fayoum weirs is governed by the hydraulic flexibility. This is expressed as the ratio of the relative change of the off take flow and the relative change of the ongoing supply channel flow (S_o /S_s).

Discharge $Q = c*h^u$
Sensitivity $S = dq/Q =(dq/dh)*dh/Q$

$$= c.u.h^{u-1}.dh/c.h^u$$
$$= u\ dh/h$$

WHERE u=1.5 for outlet weir, u=0.5 for ongoing canal supply regulating gate

The Hydraulic Flexibility F for the fayoum weir can then expressed as :

$$F = S_o /S_s = u_o.h_s/(u_s.h_o) = 1.5\ h_s/ 0.5\ h_o = 3\ h_s/ h_o.$$

WHERE u=power u of h in $Q=c.h^u$, s=supply (ongoing flow) flow
h=head, S=sensitivity and o=off take (ref Horst 1998, pp27-29).

Typically this situation gives large values of flexibility (Horst 1998, pp59-63). Zirebwa recognised this limitation and said:

"*A serious design oversight was made to have a mixture of overflow weirs and underflow weirs at the off take structure. The sensitivity to discharges and or to water level changes is not the same for the Fayoum weir and the flow regulating gates" (Zirebwa 1997, pp82).*

This suggests that there are hydraulic limitations to use of a fayoum weir in pumped supply systems. This system requires a secure simple gravity water delivery (Turral 1995). Manzungu argues that consultants who had used the same design in Egypt, were the main driving force behind the introduction of fayoum weirs at Musikavanhu (Manzungu 1999, pp133). This immediately raises the question of Agritex's commitment to the proper use of structures that were installed with their co-operation for whatever reason. There is a danger of later rejection, and farmers are left to operate them (Horst 1998, pp54-55). The danger of "orphan technology" is imminent as observed with the Bonde pumps in chapter 7 (Speelman 1990). During calibration of the fayoum weirs a number of technical deficiencies related to design and implementation were also highlighted (Debron 1999). As Zirebwa (1997) noted there were construction problems created at implementation including inadequate or reverse slopes and lack of drain outlets. Taken all together, these have required that individual weirs be calibrated in detail for accurate rating curves to be available for measurements. Another important question relates to whether the measurements are made and used to proportion flow in practice.

The researcher deliberately worked with the farmers in recording irrigation events and documenting practice in order to get to the kernel of this flow measurement issue. Musikavanhu like most schemes developed after 1990 was planned and designed for farmer management. Therefore at the core of the system operation should be an understanding of the farmers and their capability and coping strategies as an institution. These new irrigators were charged with the operation and maintenance of: a groundwater source of water; submersible pumps of international origin; paying electricity costs; and equitably distributing water using a new technology intervention that calls for use of measured flows. Yet earlier chapters showed that there is no culture of measurement (e.g. at Chakowa and Deure) and that pump maintenance has been problematic at Mutema.

6.3 FARMER MANAGED SUPPORT SYSTEMS

Crop production and marketing

The planning phase of Musikavanhu was typically characterised by a search for crops that would support the farmers' new obligation for payment of operation and maintenance costs. Assessments were carried out at national, provincial and local levels for marketing opportunities. One idea that was entertained was dry processing of fruits that had been started at a low scale by some settler commercial farmers in Middle-Save. There were also proposals to include potatoes and pineapples in the cropping program. Sugarcane was ruled out due to the long distance of over 120km to Chiredzi by road alone[12]. Despite various proposed crop plans with nice financial returns, when the scheme started operating the cropping program adopted by the farmers was closest to practice at Chibuwe, except in winter maize production. The cropping program for the winter of year 2000 for the different groups in Musikavanhu block A1 is summarised in table 6.3.1: it shows that there is a great similarity in crop choices and area planted to each crop in the different blocks. The low area planted in-group 1 was due to salinity in the area.

Basic livelihood crops

The livelihood or food crops grown in block A1 are maize and groundnuts. Table 6.3.1 shows that Musikavanhu farmers prefer to grow winter maize to wheat. This is a marked departure from observations at Chakowa, Deure and Mutema. In order to boost their income the farmers

[12] At this stage ARDA Middle Save was transporting cane to Chiredzi. It had been contracted to grow seed cane during the 1991/92 drought and had to send the excess to sugar mills in Chiredzi.

embarked on winter green maize production against general extension advice[13]. The winter maize planted in May is sold to vendors who resell it in towns and other niche markets like Deure. Farmers do not generally market the crop themselves. Summer maize and all other summer crops are planted late (November to early December) to maximise use of rainfall and therefore reduce the power consumption. Table 6.3.2 shows the irrigation intervals for cotton and maize in the summer of 1999-2000. The maize crop got on average three to four irrigation events with the rest contributed by the rains depending on the farmers' planting date. Part of both early summer and winter maize is sold green depending on the market with the remainder forming the family food reserve.

Table 6.3.1 Crops grown at Musikavanhu block A1 scheme winter year 2000

CROP	Planting Date	Group Area (bunds)						Bunds Total	Sum (ha)	% Area
		1	2	3	4	5	6			
Tomatoes	2/5-27/5	33	23	27	26	41	32	182	4.5	6.8
Vegetables		11	7	12	0	20	14	64	1.6	2.4
Páprika	15/5	0	0	15	0	0	0	15	0.4	0.6
Sugar beans	16/4-	109	160	109	154	186	147	865	21.6	32.2
Navy beans	6/5	154	186	195	266	173	221	1195	29.9	44.4
Maize	2/5-13/5	56	82	59	35	69	66	367	9.2	13.6
Wheat	18/4	0	0	0	0	4	0	4	0.1	0.1
Sum (bunds)		360	458	417	481	498	480	2689		
Sum (ha)		9	11.4	10.4	12.0	12.3	12.0	67.2		
Source: Field observation										

Table 6.3.2 Group 5 cotton and maize 1999-2000 irrigation intervals

	IRRIGATION INTERVALS (DAYS)												
	Cotton (40% area, planted 01-30/11)								**Summer Maize (40% area, planted 01-25/11)**				
NAME	1st	2nd	3rd	4th	5th	6th	7th	Total	1st	2nd	3rd	4th	Total
NM	5	6	14	31	16			**6**	40	10	27		**3**
JC	6	6	13	31	22	17		**6**	38	27			**2**
AM	5	8	20	26	15	23		**6**					
TC	6	6	16	31	22	15		**6**	38	11	27		**3**
CC	6	3	13	19	29			**5**	36	2	25	6	**4**
TM	9	3	13	12	25	6		**6**	24	12			**2**
MC	5	9	26	40	20			**5**	31	4			**2**
EM	5	11	40	20				**4**	30	16	18	21	**4**
AM	7	6	15	10	23			**5**	23	16	19	21	**4**
FM	6	3	16	9	38	17		**6**	12	28	19	23	**4**
AV.	6	6	18	21	21	12	26	**6**	30	14	23	18	**3**
Source: field observation													

Some groundnuts are sold the green market with the greater part of the crop being for home consumption. The other livelihood crops are minor vegetables like rape that is grown

[13]In the first cropping year the farmer were reluctant to sell off maize either as green or grain until the next harvest. When they realised how much they had still in stock they went into green maize marketing. The main danger is the build up of maize streak virus that seems to be taking place slowly. Extension agents cite the Nyamaropa experience, where the virus level became so high that it wiped away even the neighbouring dryland crop prompting an enforced maize cropping restriction in the 1980s.

for nutritional purposes in both summer and winter. Most plotholders at Musikavanhu have a consistent production of one to two bunds of rape for the local market. They use this to boost their income and it serves as ready cash to offset power costs.

Commercial crops

The main commercial crops grown at Musikavanhu are cotton, tomatoes and beans. Cotton was one of the major crops supported at the commissioning of Musikavanhu block A1, with farmers getting inputs. Farmers have continued to grow their dryland cotton along the Save in the former Tongogara refuge camp area. Discussions with the farmers during the study revealed that they still give more attention to these dryland cotton areas than the irrigated cotton because they have bigger areas and the soils are more fertile (as in Bonde). Some rent out irrigated fields during summer to civil servants or other farmers while they concentrate on the bigger dryland cotton crop. Cotton in the Musikavanhu scheme occupies up to 40 percent of the summer crops (bigger than the 10 percent at Chibuwe – see Manzungu 1999, pp55).

Early tomatoes planted in the summer occupy an insignificant area. The main tomato grown for canning occupied an average of seven percent of the winter year 2000 area in block A1 (see table 6.3.1). The crop was fairly evenly distributed both across groups and farmers. The modalities surrounding the growing and marketing of canning tomato are very similar to those at Mutema (chapter 5), Tawona (Vijfhuizen 1998) and Chibuwe, (Manzungu 1999). This is characterised by group contracting whereby the whole block is contracted to grow a certain area of tomato. Agents for the cannery enter into verbal or mutual contract, monitor and collect the crop as also discussed for Mutema. During harvest and collection the farmers use their local institution to monitor input supplies to individuals, record delivered boxes per farmer, follow-up and collect bulk payment, deduct individual expenditures and effect individual payments. The Irrigation Management Committees (IMC) manages the contracts because most of the farmers (73% in year 2000) are involved in canning tomato production although area per farmer is small. Transparency is emphasised and responsible representatives spend considerable lengths of time explaining the financial transactions to the individual farmers depending on their levels of understanding. The representatives who collect payments are given transport and subsistence allowances consistent with the actual cost of travel and food. The long distance of Musikavanhu to the cannery in Mutare relative to other schemes makes farmers feel as if it the last resort for both contracting and collection.

The bean crop is sold in individual cash transactions concentrated in a small window of a day to a week or a month for big producers and therefore brings what farmers call visible or tangible money. The distance of the scheme from main towns forces farmers here to enter into an additional arrangement for growing special bean varieties. The special canning varieties like navy beans are grown on contract with companies in Mutare or Harare who later resell the produce to canneries. The 1999 farmers' marketing committee, made up of a representatives from each block and chaired by a farmer holding an agricultural certificate, tried in vain to bargain for an increase in price of beans as shown in box 6.3.1. The return per investment for growing navy beans was about 2.12 $Zim to 1 $Zim spent[14].

As explained in Chapter 4, farmers like growing beans because they have a low water demand requiring, besides pre-irrigation and harvest irrigation "*kudzurisa*", only three or four and at most five irrigation events. But as observed in most schemes the low water consumption by the bean crop is not directly translated into water savings. The RIS for winter seasons show a marked higher supply over demand for virtually all schemes. In surface schemes this has largely been attributed to the system's inability to apply smaller depths of water. In pumped schemes with water metering the inclusion of pre-ploughing and harvesting irrigation events can also account for the high relative water supply. Musikavanhu farmers

[14] This is based on calculations farmers made in trying to bargain for higher prices from the agent contracting them to grow beans that he resold to the canning company.

observed the relatively high electricity bills in winter and made an attempt to enforce savings as detailed in section 6.5.

Extension services

As Musikavanhu is farmer-managed, the only direct support component from government is supposed to be the provision of extension services. Based on this objective the Block A1 hydraulic unit was only supplied with an extension worker who carries out normal extension services only. Table 6.3.3 summarises the staffing arrangements at Musikavanhu compared to situations at government schemes like Chakowa, Deure and Mutema detailed in chapter 3, 4 and 5. The staffing therefore places a lot of emphasis on the farmers' institution, the irrigation management committee (IMC).

Box 6.3.1 An attempt to raise beans price by Musikavanhu Marketing Committee

The marketing committee prepared gross margins and returns per investment with the help the local extension agents.

On the 16th of May 2000 it was resolved that farmers were to press for a raise from the 23 $Zim offered (which was only 3 $Zim above the previous year) to between 35 to 45 $Zim. The first meeting scheduled for 5th June did not materialise as the buyer did not come and only two members including the chairman attended. All farmer representatives and the buyer then met on 12th June 2000 but there were no extension workers as they had all gone to Chipinge on election-related business. The marketing committee chairman chronicled problems with paying school fees, irrigation fees, acquiring food and general lack of progress due to low bean prices. The buyer expressed sympathy with the farmers and wished he had authority to pay them 30 $Zim per kg. He was willing to facilitate their direct negotiations with the canning company, which they immediately turned down. They preferred dealing with him since he was in daily contact.

The farmers then wrote a letter the buyer took to the canning company requesting a meeting. The company could not come because they were facing fuel problems and that ended the price bargaining process for that year.

Table 6.3.3 Comparative management support at Musikavanhu and government schemes

Description	Equivalent government facilities	Farmers or farmer "hired" facilities
Study Area (ha)_	72	72
No. of farmers	60	60
Hydraulic blocks No.	1	1
No. EWs	1	1
Controller/block bailiff	Nil for this size	1 farmer
Pump operator	Normally 2 DWD employees	5 (hired by project & turned over to farmers as employees)
No. Maintenance staff	3 (10 before 1990)	Nil
Group bailiff/leader	2 Agritex employees	6 farmers
Maintenance equipment	Tractor & trailer, building tools, slashers	Nil
Administration staff	1 Clerk and 1 office orderly	Nil
Maintenance fee level	145 $Zim/ha/yr)	1500 $Zim /1.2ha/yr
Maintenance Fee payment	Poor to good	Fair
Training material	Master farmer handbooks	Overhead, boards, photocopier
Source: field observation		

Musikavanhu Irrigation Management Committees

The Musikavanhu main committee is constituted as a "federation" of the block committees. They have a complement of elected office bearers that includes chairman, treasurer, secretary and committee members. They meet monthly at the Chibuwe office to deliberate on selected scheme cross cutting issues from the various committees like marketing as detailed in box 6.3.1. Each block is hydraulically independent and therefore operational and maintenance issues are elaborated at this level as shown in figure 6.3.4. As table 6.3.4. shows the IMC is multifunctional. This may have an advantage of efficiency in that they can serve the different needs of the farmers and get a fair amount of work within their term of office.

Table 6.3.4 Office Bearers in Committees at Musikavanhu Block A1

Committee Description	Number of members
Main	9
Disciplinary	5
Audit	3
Marketing	1
Water Management	7
Total	25
Percent office bearers to farmers	42
Source: field observation	

In 1999-2000 the Musikavanhu Block A1 scheme full compliment of office holders involved 42 percent of the farmers as shown in table 6.3.4. Some individuals have expressed concern over this seemly high proportion. There are no guidelines to determine the level of representation in committees. The need for farmers' involvement in administration and finance as prescribed for IMT has tended to increase the number of committees (FAO 1999).

Farmers in a hydraulic unit elect block committee members annually whose composition is summarised in table 6.3.4. A member can be retained in the same position for several terms depending on performance. Individuals are told openly in no uncertain terms at meetings that they will lose a farmer's vote due to poor performance especially related to financial misconduct. The committee is obliged to open and operate a bank account in order to facilitate payment of electricity costs and accounting for maintenance funds[15].

Table 6.3.5 summarises the pattern of office bearers for Musikavanhu block A1 for the period 1995 to 2000. Some have always been office bearers with responsibilities changing over the years. The records and minutes and any "official correspondence" of the committees is kept by the respective secretaries at their homes and transferred to the next office bearer. In order to locate past records one therefore needs first to locate the portfolio holders.

Each committee has a constitution and by-laws that the project and Agritex help in setting up. As with all other schemes the by-laws are not yet aligned to existing laws and statutes in the country. Studies commissioned by the management-training unit revealed that a lot still needs to be done in this area.

[15] This marks the major departure from GMIS like Chakowa and Deure where farmers and IMC sometimes would not clarify if they help bank accounts. This is another area where my position within the irrigation sector made farmers hesitant to confirm their actions with respect to conditions set by government. Bank accounts are not perceived as important for simple technologies with low or no operational costs but are viewed as absolutely essential when handling operational funds as they instill a sense of security and provide proof of payment across members. But ability to provide the required financial accountability for maintenance drives successful IMT interventions as noted by Kloezen (2002).

Table 6.3.5 Summary of Office Bearers for Musikavanhu Block A1.

Post	1995/96	1996/97	1997/98	1998/99	1999/2000
Chairman	P.Chitekuteku	P. Chitekuteku	P. Chitekuteku	E. Humbe	R. Nkomo
Vice Chairman	Mrs Samu	Mrs E. Mutumbami	Mrs E. Mutumbami	Mrs.T. Sithole	P. Chitekutek
Secretary	R. Nkomo	R. Nkomo	R. Nkomo	Mrs A. Magwenzi	E. Sienza
Vice Secretary	Mrs A. Magwenzi	E. Humbe	E. Humbe	R. Mutumbami	F. Sithole
Treasurer	J.Chitekuteku	Mrs P. Mutai	Mrs P. Mutai	Mrs E. Mutumbami	Mrs. E. Mutumbam
Committee members	Mrs Matata	W. Simango	W. Simango	J. Gwezva	Mrs B. Samu
	E. Sithole	P. Mutonhore	P. Mutonhore	M. Dhlakama	B. Magwenzi
	A.Mumango		B. Sihambile	G. Magwenzi	J. Gwezva
Source: Farmers' records					

Water delivery operational support

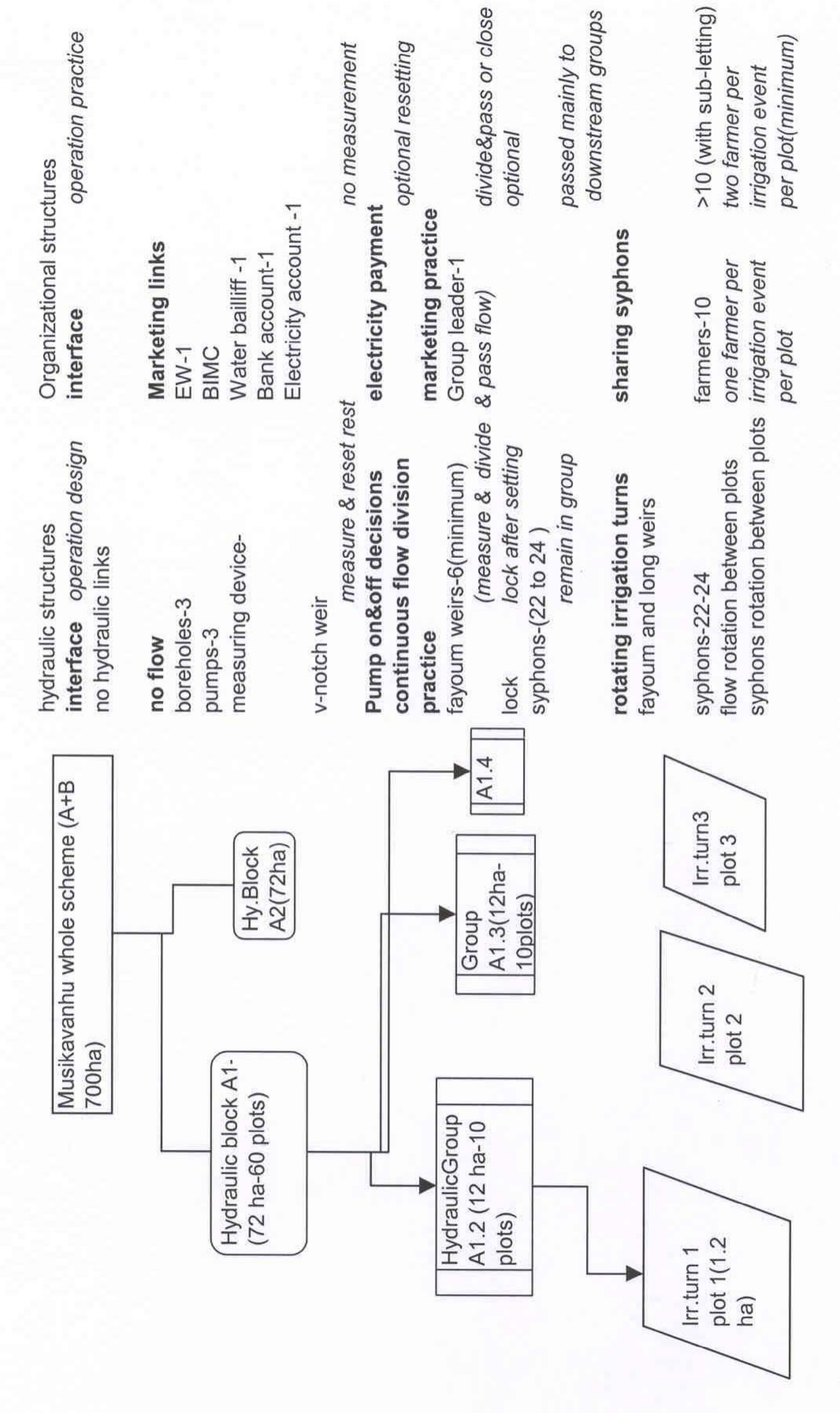
Block A1 has three boreholes that supply water to a main canal from which six equal size groups abstract continuous flow proportionately. Six group members share a bundle of 22 to 24 siphons that rotate with the continuous flow lead stream as shown in figure 6.3.4. Control of electricity and maintenance payments for the hydraulic unit is at block level. The block committee can impose water allocation sanctions to defaulters in electricity payments. It can also enter into agreements for direct payment of electricity costs for those renting plots as detailed in section 6.4. An elected non-paid water bailiff is charged with the block water control functions and is equivalent to a water controller in government run schemes.

The duties of the 'water bailiff' at Musikavanhu are:

- Instructing the operators at all borehole stations to switch on and off the pumping plant for regular supply, adjustment and emergencies.
- Following the main canal and checking for proper setting of gates and adjusting or calling for the respective group leader to adjust water as required and to make complains to the main committee as appropriate.
- Following up water to outlets of groups. This is both for water delivery and adjustments. Checks opening for any secondary outlets on each block.
- Working with the BIMC and gives recommendations to avoid conflict.
- Providing information and recommendations on the all borehole water supply to the Chairman of the BIMC and EW that is used in scheduling for enforced electricity savings, and system repairs.

The continuous stream of water is rotated among the 12 group members under one elected group leader who is not the chairman of the IMC. Group leaders receive no remuneration for water allocation. They work closely with the water bailiff in controlling water as detailed in practice in section 6.5. Group leaders and the water bailiffs recorded and collected most of data and information analysed at Musikavanhu during this study, which they did commendably despite challenges.

Fig. 6.3.4 Water delivery operational support at Musikavanhu block A1-farmer managed irrigation scheme



Community demand for their personal leadership sometimes revealed painful skill gaps for recording.[16]. Some of the farmers at Musikavanhu were actually holding qualifications equivalent to EWs and therefore their quality of data collection, discussion and problem analysis level was fairly high.

While group leaders distribute water the lead stream among the 12 group members the “informal” water bailiff distributes water across the 6 groups. The “informal” water bailiff in reality supervises the work of group leaders and therefore commands a lot of respect among the irrigators. Although there is no financial gain the individual the task is highly contested as it carries a lot of honour and is therefore part of self-actualisation for the incumbents.

Infrastructure maintenance support

Unlike the elaborate operational structure shown in figure 6.3.4 there is no structure for maintenance at Musikavanhu. An inventory of the scheme existing artefacts and their condition carried out in year 2000 revealed that there is no collective equipment or tools for the farmers to effect repairs to any part of the system. There is virtually nothing for the boreholes and electric pumps - not even a wheelbarrow or builders’ bucket for the concrete canals, nor pliers for the fence[17]. There is no one and no arrangement available to work on maintenance issues or activities for the IMC as an institution. The farmers and local staff are not in a position to monitor, evaluate and carry out any corrections or adaptations without the aid of specialists. Attempts to do this especially for borehole pumping plant have been discouraged by both the specialists who supplied the equipment and government officials.

Administrative support

Provision of support to the local institutions has been neglected although the objective of capacity building has always been included in almost all project formulations. Musikavanhu does not have government staff and offices of its own. The development project extended the Chibuwe office block some 5 km from block A1 and provided office equipment. However the farmers at each block like A1 have virtually a table and two chairs only. There is no registry or administrative arrangement specifically meant for the farmers. All facilities being used belong to Chibuwe: yet this a long way to expect farmers to walk to file independent reports (if such a system existed). There is no specific clerical service to carry out specific functions like filing energy bills. Farmers or extension agents do the follow-up payments without a systematic filing system. There is as yet no specification of services government officials are obliged to provide to support farmer-managed schemes.

Traditional Leadership

The local Chief's representative (a headman) in Musikavanhu recalled his earlier involvement in the identification of the scheme at the official opening of extension workers houses and handover of vehicles in 1998 to government[18]. The traditional leadership guided developers

[16] In some groups where an elected water control leader could not write well and perform the work they were given an assistant with " *good hand writing*". In other groups they had sufficient potential leaders who could write. The big issue was on the politics of selecting the water bailiff. I have to admit here that the two individuals who performed the task during the study are very good. They had individual "campaign" strategies and attributes that only helped the researcher to get more in depth understanding of the goings on at the scheme. The problems related to choice of these hydraulic leaders do simulate situations in the local authorities related to educational level, privileges, geographic rotation of leaders etc.

[17]While the O&M training team was complete with 3 land rovers, an accountant and offices in Mutare.

[18] Government officials, farmers and the researcher believed the EU was handing over houses and vehicles to government of Zimbabwe. They were surprised when the vehicles were later sold off to some members of the training team.

during land clearing and levelling as regards traditional requirements in handling sacred trees and burial sites. They then took a back seat leaving the IMC clearly in charge.

A sensitive but related issue is plot renting. This is practised on all schemes. However those schemes that formally involve traditional leadership in plot allocation also have bylaws that forbid plot renting as noted at Deure and Mutema. At Musikavanhu the IMC actually requires that the one renting "*roja*" be formally introduced to the IMC and they clear the outstanding electricity costs for that plot. The "*roja*" then takes over and makes subsequent electricity contributions direct to the BIMC until the plot owners makes other arrangements. This is very similar to the practice of paying electricity by "lodgers" in urban areas. The actual plot rental agreement for using the plot is restricted to the "*roja*" and plot owner. However the issue of maintenance is not addressed and this leaves a clear gap as regards sustainability.

Local Government and DWD

Local government was involved in the development stage and is noted for refusing the tarring of the road to the scheme citing high future maintenance requirements. They instead advocated for a loop road connecting Block B to the main road that Agritex turned down as not directly related to the project. The DWD was involved in the planning, and as a borehole development contractor, farmers at one time expressed interest in letting DWD manage their boreholes, but this has not materialised.

6.4 OPERATIONAL PRACTICES AT BOREHOLES

The farmers' main borehole operational activities are paying electricity and ensuring that the pumps are switched on and off as required. According to the JIMAT (2000) consultant study of Musikavanhu scheme, a "crude" analysis shows that 50% of the costs of operating and ownership are energy costs. The study recommended that the farmers pay Z$8750 per year in year 2000 up from a high of Z$3500 prompting different actions from some blocks. Block A1 farmers raised their total contributions targets to Z$7000 per year. Others enforced electricity savings (discussed later). This led to differential payments between blocks. The cost of electricity and replacing boreholes went up significantly due to the devaluation of the Zimbabwean dollar. ZESA has been increasing tariffs since 1998 using long run margin costs. Electricity tariffs had been previously heavily subsidised and state controlled.

The borehole pump stations at Musikavanhu comprise an electric switchgear and the pump head that is the delivery pipe, a water tape and water meter, as the only components above ground[19]. A transformer is usually situated nearby. There is no shed or any other type of shelter. Each block has three or four such stations. At scheme conception each station was supposed to be permanently manned by an individual who would be trained to operate and monitor the borehole operation. Currently borehole pumps are just switched on and off. There are hardly any persons monitoring the pump. Most of the boreholes are accessible throughout the year, but some in block A are inaccessible in summer after rains. The "roads" to most of the boreholes were never maintained after the drillers and pump installation contractors used them.

The pump operators were initially paid Z$200 per season by the development project, and allowed to cultivate an acre of ground at the pump station as well as have a plot in the irrigation scheme, and initially could be seen at the stations at all times including at night. They are now less visible and allowances have fallen away. Interviews with one of the oldest,

[19] This contrasts with the Mutema borehole pump station as discussed in chapter 5.

the operator for borehole A2 revealed that the farmers were reluctant to have him cultivate up to an acre at the pump station and still have a plot in the block as per original arrangement. The Block IMC took away the main field plot first. They then decided not to pay the pump attendant the agreed Z$200 per season. Left with only an acre plot by the pump station, this borewell operator had started making other arrangements. First he looked after a nearby farmer's cattle on part time basis. Later on he could not even be found: neither his children nor local farmers wanted to disclose his whereabouts or discuss the issue. The WMS and EW did not seem to have a common position on allowances and roles of a pump operator, and whether there is need to have a permanent pump operator who guards, operates and monitors the borehole stations. Most of the pump stations in other blocks are not manned at all. The informal water bailiff or other selected farmer just switched them on and off.

In an informal interview in early 1999, the EW for Block A1 explained that the problem of permanent pump operators started at the neighbouring Chibuwe irrigation scheme. The DWD pump operators there are never seen to be at the pumps. Most of them are said to just switch on the pump and then go to their irrigated fields or somewhere, and to be absent on a number of times when things go wrong or when farmers want them to switch the water supply on or off (see also Manzungu 1999). The EW explained how Musikavanhu farmers were not fully convinced that the pump operators needed to be full time, and were also reluctant to remunerate them well or help in putting up shelter for them to permanently man the pumps. In short, the recommendations of the geo-hydrologists report on recommended practice were nullified in the farmers' mind by the Chibuwe experience. But the farmers have most probably had no sight of the consultant's recommendations. Nor perhaps do the operators. They keep their records in the electricity panel boards, as there is no shelter and some do not want to take them home. One operator told that these records sometimes got used as tobacco wrapping paper.

Some records supplied later by the group leaders seem genuine although initially they had gaps. However evidence in block AI and reports from other blocks show that group leaders and some selected farmers like the chairman and secretary were increasingly taking the role of pump operators. They took water meter readings and electricity consumption figures. The relegation of this 'management through measurement' concept by both the farmers, local Agritex and WMS do send signals of further problems, that the prime importance of the borehole and their records in the irrigation system may be minimised. It undermines the leverage possible for the system, and the original concept of **"farmer hired operators"** needs to be revisited in the light of the new experience farmers have had to date.

A Jimat report (2000) that reviewed the Musikavanhu project status recommended that the farmers fence off the pump unit equipment and insure it against theft or damage, but was silent on the needs for and of pump operators. It re-emphasised the need for recording of borehole output and calls for "farmers to get into this habit", and it identifies a need for farmers to be trained in routine borehole maintenance although it lacks relevant detail.

Maintenance and pump repairs practices

A pump operator for group A5 is said to have "repaired" borehole no.1 for block A1 by resetting the switch and removing a lot of ants (*masunzwi*) that were allegedly causing a power cut. He claimed that the problem with borehole 3 was due to ZESA connections. This pump operator, reported to have electrical qualifications, actually charged farmers Z$1000 for the resetting. He was given half with the other half paid after one season. The WMS however says that the contractor that installed pumps referred to this farmer-financed initiative as "tampering by the peasants" and it was discouraged (personal communication).

As discussed earlier farmers were paying all electricity costs well but varying amounts were being paid for maintenance with block A3, A4 and A5 making no contributions at all.

Block A1 farmers are paying Z$1000 per year, A2 are paying Z$500 per year and Blocks B farmers are all paying Z$1500 per year. Payment levels are determined on a block basis based mainly on farmers anticipated future needs. At Musikavanhu these maintenance contributions seem to have been largely used to bridge gaps in operation fees. Farmer groups use the funds to pay electricity and other urgent issues[20]. Discussions with farmers in block A1 revealed that there is no clear maintenance strategy and plan. The donor repaired two boreholes pumps "damaged" by cyclone Eline, and drilled one replacement well before pulling out. Although farmers in different blocks have put varying amounts of funds aside for maintenance and repair purposes, these funds have in the main not been used because there is no plan or obligation to use the funds in caring for the infrastructure.

The drive by ZINWA in 2000 to get farmers to pay for water created a window of opportunity for Agritex and the SSIP programme to engage in dialogue with ZINWA. They met farmers' leaders and proposed one water charge that would include water, maintenance, power costs and replacement. The WMS took a keen interest in these meetings. Farmers at one time preferred to make maintenance and operation payments to one organisation only. The farmers were eager to get ZINWA to take over but when they reviewed the institution's performance at neighbouring Chibuwe and Mutema they decided to hold on for a while. According to the former WMS their main problem is getting service providers to help in repairs and marketing into the Musikavanhu area.

Musikavanhu field canal, drain and road maintenance practice

Farmers have not yet been involved in the repair of canals that they are supposed to undertake on their own. The maintenance schedule and calendar prepared by the local EW as part of his extension advisory service to the Musikavanhu block A1 irrigators shows that canal maintenance is supposed to be done once a month. This should include: cleaning out the canals and drains; removing mud, silt and stones; repairing canal embankments; weeding and destroying anthills; repairing fences, roads, maintain bridges and flushing the system out once every season using scouring valves so that all the sand and silt in the pipeline can be removed before it clogs the system. Over-topping or poor siphon use has eroded most embankments leaving canals sticking out of the ground, even though the scheme has been operating for only a few years. The situation is worst at the tail-ends of groups 6 and 5. Farmers clean grass along their canal reach. Some farmers or their hired dryland neighbours only remove the silt and weed their respective areas but leave the embankments without repair. Currently drains, roads and fences are not cared for. At the time of study the farmers were not following any organised maintenance program at all. The IMC admitted that they failed to stop farmers from growing crops in drains.

Water Delivery Performance

The Relative Irrigation Supply of Musikavanhu block A1 shown in figure 6.4.1 was calculated using data obtained from the recording done by the pump operators. At the start of the cropping season the relative irrigation supply (RIS) is far higher than unity due to supply far exceeding the crop water requirements (CWR) but this falls to below unity in June to August indicating a deficit in winter. The fall in RIS in summer is attributed to the contribution of the rainfall as well as an allowed deficit as discussed for the Deure case. The graph shows a typical case of excess delivery during the cropping periods in April and May for winter and mid-September to mid-October in summer.

[20] One senior specialist has charged that the Agricultural Revolving Fund (ARF) that was conceived as a stepping-stone in the handover of O&M in government schemes is also being used to bridge T&S finances by government officials. If farmers were to learn this then they will surely confirm the problems in the train-the-trainer approach.

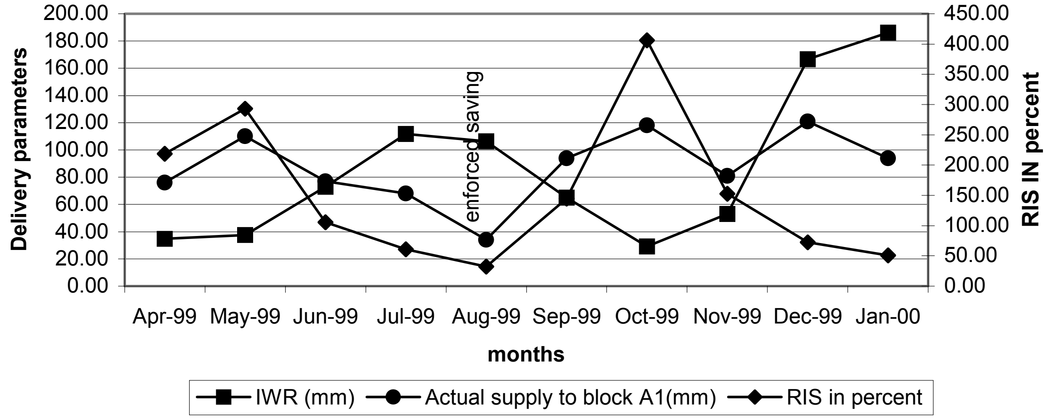


Figure 6.4.1. Musikavanhu A1 Delivery Performance

At block level, farmers' actions are conditioned by the need to control volume of water pumped and subsequent energy cost. The scheme has a high RIS at the beginning of the winter and summer season in April and May and September to November respectively. This is due to the combined effect of low water demand due to crop establishment, change-over that is accompanied by harvesting and the water required for pre-ploughing and pre-planting. The RIS for the winter crop goes below 0.5 and is much lower than that recorded in Deure as discussed in chapter 4. This is due to the farmers' deliberate policy of enforcing water saving by restricting water supply to the winter crops in order to cut down on the power costs. Farmers at Musikavanhu were not concerned with water wastage before they started paying electricity (Zirebwa 1997, pp84). The pumped schemes studied by Makadho did not pay power bills directly and therefore the issue of farmers practice in saving water was never explored (Makadho in Rukuni et al 1994, pp59).

The enforcement is illustrated by the pattern of irrigation events for Group 5 in the periods 7 to 13 June, 7 to 16 July and 27 to 30 July of year 2000 as shown table 6.4.1. The farmers imposed these water savings without consulting the irrigation agency or the water management and training consultants. The decision was based on their financial assessment of the power bills and thresholds that they set depending on their capacity to pay. This decision process is typical of farmer-managed pumped schemes and sometimes results in farmers opting to grow crops different from agency recommendations or to abandon cropping at times or to stop irrigation entirely. This explains the low RIS that was obtained in 1999 in the same months of June to August whereby demand exceeded supply that was available. This contrasts with the Deure situation in chapter 4 where a low RIS for the summer crop RIS was informed by the hydraulic limitation of the canal to supply a sharp peak IWR due to farmers planting an early summer crop after canal cleaning.

Theoretically the farmers have two options of controlling flow: (1) they can switch off one borehole module, reset continuous flow to each group at a lower proportional level and reduce the number of siphons in use per group and (2) they retain both wells operating and pump for shorter periods for all farmers in all groups. In this latter case there is no need to reset the fayoum weirs. A third option combines both options 1 and 2 whereby only three groups are given half the flow as required with no resetting of the fayoum weirs.

Figure 6.4.2 gives the average flow calculated from data recorded by the pump operators' records, and bears out these practices. The average flows recorded after April 1998 are consistent with the use of two pumps of similar discharge at borehole no. 1 and 2. Borehole number 3 with lower discharge has been used rarely (farmers pointed out that it uses more power that is consistent with its lower rest water level and lower recharge. Effectively this leaves the farmers with no working stand-by pump as per the original objective.

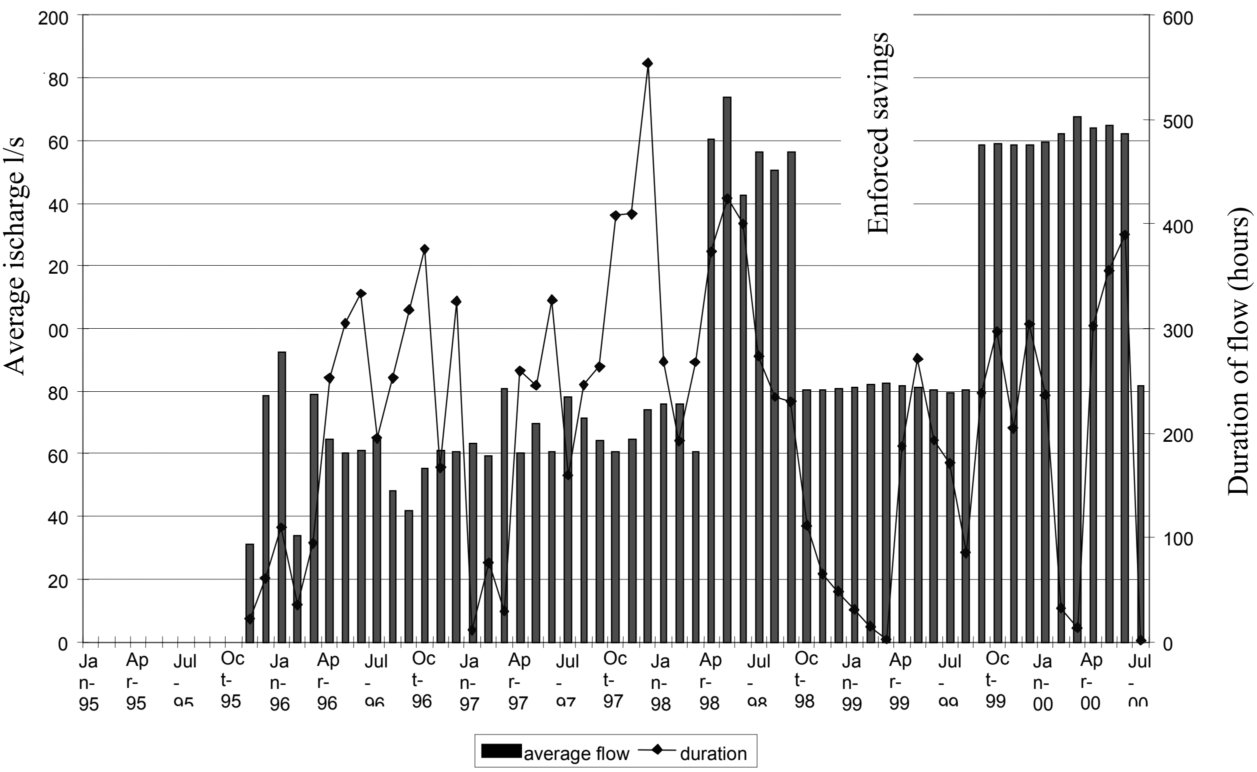
Table 6.4.1 Musikavanhu block A1 Group 5 irrigated beans (bunds) winter year 2000

Date	Farmer number 1	2	3	4	5	6	7	8	9	10	Sum	
9-May-00			16								**16**	
10-May-00											**0**	
11-May-00	16										**16**	
12-May-00											**0**	
13-May-00											**0**	
14-May-00											**0**	
15-May-00				16							**16**	
16-May-00		4									**4**	
17-May-00						16	12				**28**	
18-May-00							4	16	16		**36**	
19-May-00			16		12						**28**	
20-May-00											**0**	
21-May-00											**0**	
22-May-00	11	16			4						**31**	
23-May-00	5						16			16	**37**	
24-May-00										2	**2**	
25-May-00				16						14	**30**	
26-May-00					16	12					**28**	
27-May-00							16		10		**26**	
28-May-00								16	6		**22**	END OF FIRST IRR.
29-May-00	5	5	4	16							**30**	
30-May-00	14	10	12								**36**	
31-May-00	2		10	16	6						**34**	
1-Jun-00			16		16						**32**	
2-Jun-00						8	16		16		**40**	
3-Jun-00						8	16	16			**40**	
4-Jun-00	14	16									**30**	END OF 2ND IRR. EVENT event
5-Jun-00	4										**4**	
6-Jun-00	7			16	16		16		3		**58**	
7-Jun-00											**0**	
8-Jun-00											**0**	ENFORCED ELECTRICITY COST SAVING 1
9-Jun-00											**0**	
10-Jun-00									9		**9**	
11-Jun-00											**0**	
12-Jun-00											**0**	
13-Jun-00											**0**	
14-Jun-00		7	3			6		16	4		**36**	
15-Jun-00						6				23	**29**	
16-Jun-00	12									9	**21**	
17-Jun-00	11	16	2								**29**	
18-Jun-00			30	16	3						**49**	
19-Jun-00											**0**	
20-Jun-00							16				**16**	
21-Jun-00		5									**5**	
22-Jun-00				14	16	7					**37**	
23-Jun-00						9	16	6	16		**47**	
24-Jun-00			7					10			**17**	
25-Jun-00				16	16	12	11				**55**	
26-Jun-00							5	16	16		**37**	
27-Jun-00											**0**	END OF 3RD IRR. EVENT
28-Jun-00	16		4							16	**36**	
29-Jun-00			12	16			16				**44**	
30-Jun-00	16	16	2							16	**50**	
1-Jul-00			14	16	16	8					**54**	
2-Jul-00						8	16	16	16		**56**	
3-Jul-00											**0**	
4-Jul-00			7	5	3						**15**	
5-Jul-00											**0**	
6-Jul-00				11	16		16		3		**46**	
7-Jul-00								16	13		**29**	
8-Jul-00											**0**	END OF 4TH IRR. EVENT
9-Jul-00					3						**3**	
10-Jul-00											**0**	
11-Jul-00											**0**	
12-Jul-00											**0**	ENFORCED ELECTRICITY COST SAVING 2
13-Jul-00											**0**	
14-Jul-00											**0**	
15-Jul-00											**0**	
16-Jul-00											**0**	
17-Jul-00	16	10								16	**42**	
18-Jul-00			16	16	8						**40**	
19-Jul-00		5			8	12	16				**41**	
20-Jul-00											**0**	
21-Jul-00				16	16						**32**	
22-Jul-00							16	8			**24**	
23-Jul-00			2			16		8			**26**	
24-Jul-00			22	16							**38**	END OF 5TH IRR. EVENT
25-Jul-00			8	16	16						**40**	
26-Jul-00					16			16	16		**48**	
27-Jul-00											**0**	
28-Jul-00											**0**	ENFORCED ELECTRICITY COST SAVING 3
29-Jul-00											**0**	
30-Jul-00											**0**	
31-Jul-00		12	16			2					**30**	
1-Aug-00		5									**5**	
2-Aug-00						7					**7**	
3-Aug-00											**0**	
4-Aug-00											**0**	

Source:Field observation

The duration of pumping in figure 6.4.2 shows typical high deliveries in the winter cropping months of April to June with a slight drop in July to August followed by a summer peak in October and November. This is quite characteristic of the two season cropping demand pattern for most schemes as evidenced by supplies to the gravity schemes in chapter 3 and 6. The lowest demand months are normally around January to March and these coincide with crop change over and the rainy season.

Fig 6.4.2. Musikavanhu A1 monthly discharge and duration of irrigation



6.5 WATER MANAGEMENT AT MUSIKAVANHU

Practice and performance in across-group distribution

In practice farmers groups respond to system flow changes, as they perceive fit- especially to save water wastage as obvious drainage loss. Group leaders or other farmers close off their weir outlet after completing irrigation as opposed to the theoretical requirement to leave the outlet open to maintain proportionality. This is not always accompanied by the switching off of one or more borehole modules. The farmers' behaviour is governed by the need to control the energy costs. The reality is that extra flow is sent down the ongoing canal and the greater proportion of it is discharged to the other outlets with the minimum going down to the end of the distribution canal. The other farmers are not normally aware that this is the extra water what they witness is overtopping of the canals. They normally shout for extra siphons from upstream farmers and it takes a long time before they have adjusted to the new flow. During this time the canal embankment will have been eroded as shown in photo 6.5.1.

Stealing water at group level

The other practical reality is that upstream farmers lower their ongoing gates and increase outlet discharge reducing flow to the downstream farmers. The worst affected are lower most groups 5 and 6 who are disappointed with the distribution of water. They do not have a reliable and adequate stream of water (Zirebwa 1997, pp84). The system is not flexible enough for them to negotiate meaningfully with the head-end farmers (a situation that resembles Chakowa see chapter 3). Surprisingly there are no flow recordings or measurements and yet these possibilities influenced the choice of division structures. Only a limited number of recordings are taking place at the water meters (Horst 1998, pp67). At group level what is therefore important is the total volume that each outlet discharges each day rather the level of initial setting, as farmers interfere with the settings at any time of day (Zirebwa 1997, pp58). Farmers also found it difficult to re-set flows in response to borehole fluctuations especially contributed by borehole no. 1 *(ibid)*[21].

Photo 6.5.1 Siphoning practice on left canal bank and erosion of the left embankment at Musikavanhu

Musikavanhu Field application uniformity and siphon use

In 1997 Zirebwa studied water application performance under operational recommendations at Musikavanhu block A1 while most the scheme was still under implementation. A similar study was carried out in year 2000 and the results of both studies are given in table 6.5.1. While the application efficiency has decreased the distribution uniformity has increased between the two comparative studies.

Table 6.5.1 Performance parameters for Musikavanhu block A1

Year	Ea(%)	Er(%)	CU(%)	DU(%)	DPR(%)	TWR(%)
1997	65			86		
2000	13.4	100	93.98.	91.33	60.3	26.31
Source: Zirebwa 1997 and Mada 2000.						

Zirebwa's study showed that the performance parameters depended on the stream size, the land slope and the crop being grown and it's the roughness of the field (Zirebwa 1997). It was recommended that the number of siphons per farmer per border be increased from four to six. Currently the scheme uses 8 to 10 siphons per farmer per border. This has contributed to excessive runoff from most of the fields as evidenced from the high tail water ratio (Mada 2000). In Musikavanhu block A1 there are very few fields that close the border ends leading to a lot of cultivation of crops in the drains utilising tail water. This practice is not found in most schemes in Zimbabwe and is attributed to the use of proportional division structures.

[21] Borehole no.1 has a high drawdown during operation that significantly affects discharges. The farmers in the upstream blocks will maintain their discharges by adjusting the ongoing gates thus sending the lower groups a deficit to share equitably until the last group that gets the unknown remainder.

At Musikavanhu they now use a shared bundle of 16 to 22 of siphons per group that were supplied at scheme development in contrast to half that number used at most schemes like Deure and Chakowa. Each farmer uses all 16 to 22 siphons at the same time and therefore irrigates two borders per time as shown is photo 6.5.1. Although they finish irrigating in a shorter time there are relatively more losses of water from Musikavanhu farmers during irrigation than other schemes[22]. In block A1 there is a problem of overtopping that emanates from the insufficient siphon head. This occurs where the herring bone canal arrangement was used but the levelling was not sufficient to provide sufficient head on both sides[23]. There is also significant overtopping at drop structures due to low head. Some farmers do not yet use soil erosion protection techniques like use of stover and plastic bags at discharge contact points as observed at Chakowa and Deure (a practice possibly ingrained into them by the Irrigation Managers). Musikavanhu farmers preferred to complain about the poor levelling that was done by the contractors.

Land levelling at Musikavanhu

During the research period the Musikavanhu training team organised for a re-levelling exercise to be undertaken in the operational blocks that were reported to be giving problems to farmers. The study block A1 was also included. This made it unnecessary to embark on an extensive uniformity study. Attention was however drawn on the process of land levelling, where the "two philosophies" for land levelling clashed[24]. Some local officials the preferred the more accurate (but more laborious) least squares method that had been applied to Deure and other schemes in Manicaland. The senior consultant advised on the simple profile method whereby a few profiles for each field are pegged out (by EWs) and the rest is left to the experienced grader operator. A stormy meeting resolved that the senior consultant's approach be tried first. The first two blocks were therefore levelled without a "proper" grid. A review mission commented on the "ineffectiveness" of the approach as they physically observed the grader operator toiling to and fro to level land with little ground support to guide and show where to cut, haul and fill. Agritex officials, farmers and EWs complaints only added to the review mission's observations. Subsequent blocks were levelled using the traditional grid and least square method. The planning of the remaining re-levelling was again be-devilled by the same methodological argument with the WMS preferring again to circumvent the least square method. The argument this time besides the simplicity that was emphasised before was that it

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[22] Farmers generally team up to irrigate or at least two or three members of the family have to be present during an irrigation turn.

[23] Some farmers report that they always get their fields irrigated by their neighbours due to unequal head.

[24] There are two approaches to land levelling. The first is to provide the best slope for the water supply, assuming some standardisation over a larger area. The other is more local, and involves levelling the field with minimal earth movement, and then varying the water supply to the field (recognising that slopes and soils also can also vary along and across a field). The least squares method used in land levelling requires surveying and staking of fields at 10m intervals for smaller fields (30m for larger fields). These measurements are then put into a series equation to look at slopes in both directions through regression (hence the name) and later a planar surface. The other method involves less staking, simply to study variation down and across a field. A mechanical grader can move around 230m^3 an hour, or about 1-3 hours levelling per hectare depending on the problem. They can work with both estimation approaches, but the "best general slope" (usually also least squares method) will require action over many bunds thus disrupting a lot of farmers, whereas the local method can work on one or a few narrow bunds at a time and respond to local information, and is thus seen as more farmer-friendly. For an interesting study on communication problems between irrigators and engineering over field levelling, see Scheer (1996).

would involve too much surveying and that large blocks had to be put out of production in order to allow a reasonable size of plane.

Motorised graders were therefore hired and immediately started working on individual farmers' field that were giving "problems". The researcher witnessed a field where soil was moved and heaped in a road to a man's height. The farmers soon discovered that the field was now the lowest point and all drains started filling it up even though it was done in the dry season. The re-levelling simply was not well planned and supervised. The operator was instructed to take the soil back into the field after someone gave a shout to the training team. During discussion the farmers lamented the waste of money. Then a local farmer who holds a certificate in agriculture clearly articulated the land levelling requirements to fellow farmers and proposed that he be given responsibility for the survey and land levelling supervision to get value for money. This earned him some mileage and he successfully won the water bailiff portfolio in the elections.

Irrigation events per farmer per crop at Musikavanhu

Group leaders monitor irrigation turns and also determine irrigation turns within each group. To minimise costs, block leaders impose periods of no pumping that together with the group turns eventually determine the final number of irrigation turns for an individual farmer as shown in table 6.5.1. Farmers apply fertiliser after an irrigation event and therefore delays in irrigation therefore translate to late fertiliser application and thus have a more significant yield reduction effect. Like other schemes water is applied to facilitate pulling out wheat, beans and groundnuts "*kudzurisa*". Like other pumped sprinkler schemes Bonde and Mutema, Musikavanhu tends to limit applications related to maize stover management. Table 6.5.2 and table 6.5.3 below summarise the average irrigation intervals and average hours per hectare for three groups in block A determined from the records kept by the farmers in year 2000[25].

Table 6.5.2 Irrigation schedules for groups 2, 5 and 6 for beans

Group	**Irrigation event number**						
	1st	**2nd**	**3rd**	**4th**	**5th**	**6th**	**Total**
2	18	29	16	18	7	7	95
5	33	16	10	7	10	9	85
6	29	16	13	14	12	11	92
Average interval	27	20	13	13	10	9	92
Average days Cumulative	17	47	60	73	82	90	
Source: field observations							

Table 6.5.3 Average irrigation hours per ha for beans for groups 2, 5 and 6

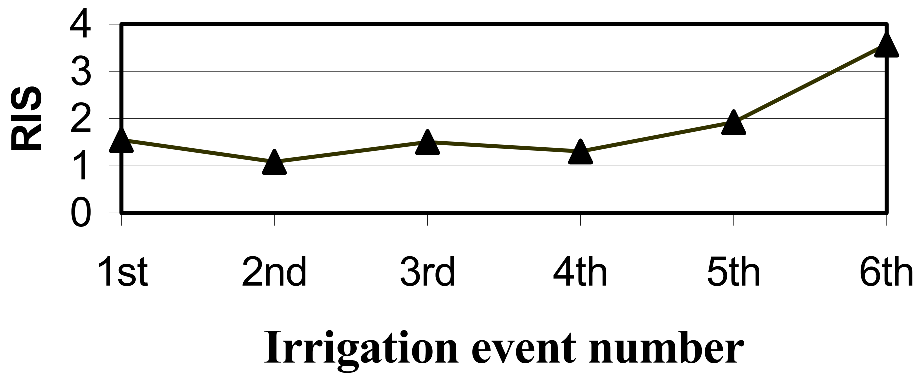
Group	**Irrigation event number**							
	Pre-irrigation	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**Total**
2		8.1	7.0	6.8	8.0	7.9	9.1	
5	20.1	13.6	9.2	10.0	7.7	9.2	7.1	
6		8.4	8.9	7.8	6.0	7.7	7.0	
Mean depth (mm)	212.3	86.5	68.8	70.8	58.0	66.7	63.1	413.9
Source: field observations								

[25] The records were checked and compiled by a research assistant who was resident at the scheme from February 2000 to July 2000.

Tables 6.5.1, 6.5.2 and 6.5.3 show that the farmers plant almost the same areas to beans and follow the same irrigation schedules and apply water to beans in fairly equal times especially in the last three irrigation events. The exact schedules followed by each group vary depending on the planting dates and actual area. **This shows that the equity objective of using the fayoum weirs as proportional division structures is broadly achieved.** All farmers are really accessing water deliveries in a similar manner. The first practical reality in system operation is the vulnerability to manipulation of gates by mainly upstream farmers to get more water than downstream farmers. The second and major issue relates to farmers defying the distribution system design requirement that for proportional and system integrity to be prevail water should flow past a block to a drain rather than be passed on to the downstream or closed off in order to reduce electricity cost. The perceived and real priority and conditions necessary to achieve proportionality and energy savings seems to be the centre of the problematic.

Figure 6.5.2 shows the RIS for beans at Musikavanhu. It shows that the last two irrigation events contribute to high water application that is not agronomically accounted for by the CROPWAT calculated RIS. The last irrigation event which can be the 5th or 6th is for harvesting beans. The actual depth applied cannot be reduced in practice with schemes like Musikavanhu due to surface system inability to apply small depth (Pereira 1996).

Fig 6.5.1 Musikavanhu RIS for beans



A culture of growing sugar cane and bananas in drains has started. The farmers in reality are simply using the additional operational losses that are inherent in the use of proportional division structures (Horst 1998). But their use with pumping costs directly paid by farmers raises issues of perceived satisfaction. In other surface schemes, even without lift requirements, losses at the field edge can attract a fine. This is the farmers' idea of actualisation that is consistent with the use of gated systems with minimum cross regulation (Langford and Gowing 1996, 1997).

6.6 CONCLUSIONS

Uphoff outlined a concept of progressive institutional development assuming that with increased farmer knowledge over time there is a shift from attention to the civil engineering or water delivery through to production and then water management focus (Uphoff 1999, pp53;

Skogerboe and Merkely 1996). Turral and Kloezen also document that IMT has been largely informed by collective action studies by Ostrom and her colleagues and students on simple traditional FMIS schemes that are mainly gravity surface systems (Turral 1995, Kloezen 2002, pp10, 33). This suggests that there is a gap in knowledge about the time trajectory of the technologically sophisticated systems with pumps.

This raises serious questions on whether the efforts that Government and the EU have put into strengthening the WUA for Musikavanhu and the current discussions to turnover management at Mutema are indeed well informed. The technology chosen put both high financial demands and skills requirements for effective operation on the system. Ideally also there is need for a wider maintenance support service (public or private) that can back up the everyday operation work of the FMIS at Musikavanhu. The implementation and training so far has focused on the local institutions, but not thought about the wider support needed, and the institutions are still being pushed 'by exhortation' rather than by reality. While responsibilities have been transferred to farmers, they were never involved to major technological decisions. Rather a technical arrogance has carried on among central office and project designers where farmers are excluded from debates even when selected techniques are thought to be more in their interests (as with levelling). While the heavy disciplinary control of the irrigation manager has been removed, technical experts still seem to have difficulties in working with farmers, and no practical capacity for terotechnology has really been developed for this irrigation system - nor for FMIS in general in Zimbabwe. A well supported training program designed to support adoption and handover of sophisticated a WDSS failed to build farmers' confidence in the system as an FMIS.

Economic not hydraulic reasons control farmers' decisions at Musikavanhu. The dominance of the pumping decisions in this case illustrates the need to thoroughly understand the system practices before interpreting the performance parameters. It also underscores the need to consider the farmers' financial status and perception in design processes (Tiffen 1990).

Where next for Musikavanhu?

At Musikavanhu (unlike Mutema) the pumps are working and farmers are paying operational costs. The fayoum weir proportional system is functional and effective (if inefficient) as evidenced by all groups growing the same crops at the same time (as observed at Deure but unlike Chakowa). However the system of borehole pumping into proportional division is not known to be sustainable as an FMIS in the long run. Several past consultants and even Agritex engineers all felt this uneasiness. The Musikavanhu farmers have clearly stated that they are not capable of sustaining the borehole pumps from a terotechnological point of view. The system is too sophisticated for them. No amount of training is likely to address this issue. The short term solution is for government to accept this fact and establish a facility that provides transparency and encourages farmers to pay maintenance fees. The fees can be used appropriately for repair of the simple canal delivery, road, drain and fence system. They also need to be appropriately invested and managed to enable future use as and when required for the borehole and pump system monitoring, repair, rehabilitation and modernisation. In the medium term such services and their management can be devolved to an appropriate service provider (public, private or joint) with central government retaining policy direction roles.

One new design leverage lies in seeing the scheme as part of the Middle Save Development program and water delivery network in both time and space. The last stage would then to factor in or allow the evolution of an organic institution to run the water delivery system and support maintenance on a sustained basis in the area.

A longer term leverage to get sustained water delivery for the Musikavanhu scheme lies in the development of a gravity canal supply system linked directly to the reservoirs Ruti, Rusape and Osborne. The link could be near the proposed Bonde offtake. A proposed reservoir site already identified in this area would provide storage necessary to enhance management. It could also enhance water management for the Bonde-Deure system. A right bank canal linking the Musikavanhu-Chibuwe schemes (1000ha) to Mutema and Tawona (600ha), to the ARDA and settlers estates (total 8000ha), and further zones like the Kondo business area can also be incorporated into the supply network to fully utilise the capacity of the Osborne dam. The project can be phased and additional link canals developed to link the storage from the Rusape and Osborne dams. The whole plan should already anticipate utilisation of the proposed Condo and Chitowe dams (although these will inundate parts of Chibuwe and Musikavanhu if developed).

This long term plan calls for the re-visiting of the cropping program to include more lucrative crops like sugar cane and development of sugar mills. The energy savings in pumping can be used for the sugar mills. The boreholes developed in both Musikavanhu and Middle Save can continue to provide the security required to bridge drought periods and also to manage groundwater levels. The first benefit of this network approach is the reduction or elimination of electricity operating costs and unnecessary use of pumps. Secondly it would substantially help in addressing the Save River siltation and flooding problems. Thirdly it allows for a new conjunctive use approach of borehole water that is consistent with experience elsewhere in countries like India and Pakistan, and which is new but maybe necessary for Zimbabwe.

7 BONDE: PUMPS, PEOPLE AND WATER CONTROL: EXPERIMENTS WITHOUT LEARNING?

7.1 INTRODUCTION

The Bonde[1] irrigation scheme development was conceived in the 1960s before the construction of the Ruti dam in 1970. It was supposed to be one of the smallholder schemes to be constructed so as to utilise the additional storage that the Ruti dam would generate in excess of the supplies to the neighbouring Deure and ARDA's Chisumbanje irrigation schemes. It actually shares an intake site with the Deure scheme. Eventually, in the late 1980's, it was designed to suit new ambitions of irrigation post Independence.

The scheme involved a two-phase pumping lift, to supply a new 'draghose' type of sprinkler technology to a large scheme of 700 ha - an area beyond anything organised for the smallholder sector before. New policies also dictated that the system should be entirely farmer-managed[2] after an initially supported phase of two years. While an Italian firm did the first design report in 1986, the Dutch government initially financed the scheme development from 1992; but the allocated funds ran out and implementation has continued under the public sector investment program (PSIP): currently some half of the scheme (the most complex part) is developed. The scheme's design and operation also got shaped by bureaucratic politics, with DWD designing only the river pumps and the conveyance system to the field edge, and operating and maintaining the river pumps. Agritex was to take charge of design of the design of the booster pumps, distribution and application system, and responsibility for the training of farmer-operators of the second phase of pumps.

While the technology suggests there should be a qualitatively different production output to cover the costs of operating such an expensive system, in fact the scheme produces similar crops to Deure. It is dependent on tomatoes and beans as cash crops and otherwise growing maize. Bonde's story is thus one of a struggle to operate and maintain a sophisticated system, with high skills demand and high costs, which have been a permanent struggle for farmers.

This chapter first looks at the unpredictable course of decision-making shaping the Bonde design. While Bonde fitted with the technological trajectory taken by Zimbabwe (see Chapter 2), in fact several economic and design criteria that might have earlier blocked the choice of technology seem to have been missed. After a summary of cropping choices, the chapter then looks at the key actors making up the management subsystem at Bonde, and their struggles to organise the services and electricity payments needed to keep the scheme running. The chapter then looks at peoples' actions and performance to keep the scheme running, and in the field application of water. The conclusions are that the system technology is too expensive and difficult for the farmers to manage the system and its field technology

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[1] According to the local member of the central committee of the ruling party ZANU (PF), the scheme name has been wrongly referred to as "BONDE" due to an error made in naming the river on the maps. The locals call the river "BONDA" and it is their desire to have the scheme properly named as such.

[2] "*all irrigation schemes should be self sustainable with minimal support from the government. In case of Bonde irrigation scheme a gradual weaning of farmers from government support is proposed and a grace period of two years is suggested. After the grace period, farmers will be responsible for the operation and maintenance of all infield works. The maintenance of common irrigation equipment that is pumps, main and secondary pipelines as well as payment of electricity will be responsibility of the farmers through their irrigation management committees*" (Bonde design report 1992, pp 37-37).

effectively, and a brief overview is given of farmers' actions to date to get a gravity replacement system.

The first blocks of the system began working in 1998. Since then, however, pump breakdowns and electricity cut-offs have caused regular interruptions and inefficiencies in working. No one will acknowledge any involvement in pump choice or design because of its controversy. All this has made Bonde a difficult scheme to research but it was studied here because of its importance to the design debate in Zimbabwe.

7.2 DEVELOPMENT OF THE PUMPED DRAGHOSE OVERHEAD SYSTEM

The scheme development started in the late 1980s with DWD head office designs branch constructing the pump house at the Deure weir, main pipeline, conveyance canal, night storage dam and pipelines distributing water to the different blocks as shown in schematically in figure 7.2.1. Agritex Irrigation branch staff at head office - with assistance from FAO - carried out a feasibility study for block CI (100ha) that was completed in 1992. Based on this study construction of infield works for this block started in 1994 and was completed in 1996. Work in Block A (160 ha) started in 1996 and was completed in 1998 when this study started. Work on design and implementation of the in-fieldworks for the other blocks is still in progress.

The feasibility study made a detailed comparison of both drag-hose and semi-portable distribution and application subsystem costs whose difference is quite marginal. The semi portable has short conventional aluminium pipe laterals while draghose has a lateral complement comprising buried PVC pipes with hydrants to which are connected lengths of hosepipe. The feasibility study did not attempt at all to make any reference to gravity or surface irrigation as alternate technologies[3].

The report refers to pumping more than 50m when in reality the total scheme-pumping requirement is 80 m for the river pumps and an addition 60-65m for the infield works. There is evidence that either these pumping costs were never fully considered or there was a presumption that the state would continue to pay electricity costs. The feasibility report did not consider two stage pumping in its economic calculations (the infield designers may not have known the actual head required for the whole scheme to operate). The local Chief and farmers were adamant that an idea that farmers would pay electricity costs for river pumps was never discussed at the project launch. Table 7.2.1 shows the results of an economic analysis of the scheme as done for the project with and without considering the river pumps and their O&M requirements.

[3] The following statement was used to disregard important gravity and surface irrigation alternative investigations "*..the topography and soils of the land combined with difference in elevation between the water source and the land favour the adoption of sprinkler irrigation system…As the pumping head from the abstraction point to the main night storage dam is more than 50 m and in view of the low efficiency of surface systems the operating costs of a sprinkler options in addition to high capital costs of surface irrigation in relation to sprinkler system. Hence the two sprinkler options were designed for…* " (Bonde design report 1992). The second part of this statement was taken directly from the irrigation manual without any modification and analysis (Irrigation manual 1994, pp 176). The example in the manual considered the case of irrigation on the highveld where the climate is moderate.

Fig 7.2.1 Schematic layout of Bonde

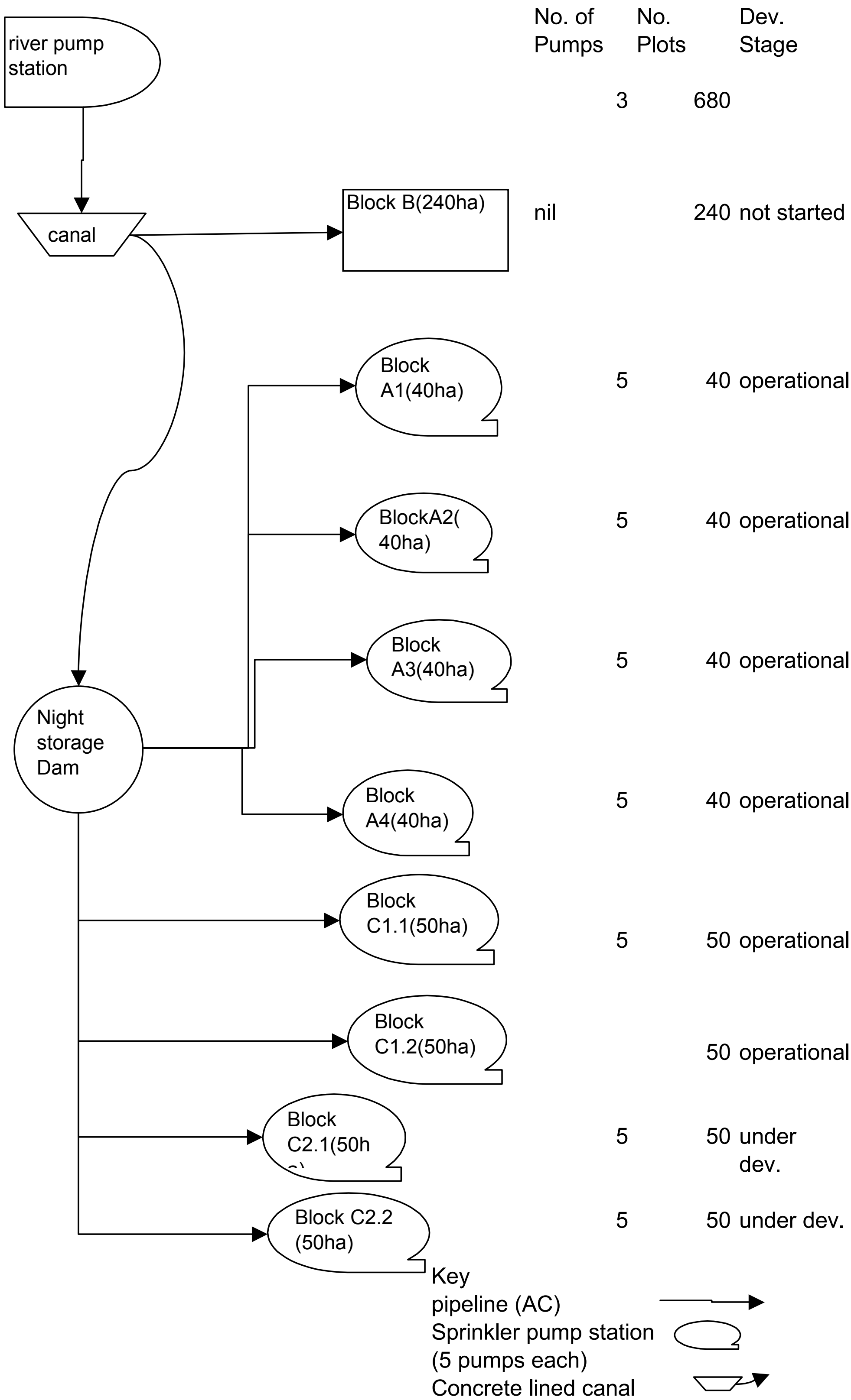

Table 7.2.1 Comparative Bonde project worthiness with and without river pumping costs.

Indicator	IRR%		B/C Ratio		NPV (Z$)	
Sprinkler application Alternative	Without river pumps	With river pumps (research review)	Without river pumps	With river pumps (research review)	Without river pumps	With river pumps (research review)
Draghose	10.33	6	2.82	1.27	142 756.96	-339984
Semi-portable	8.81	7	0.94	.98	237 199.64	-593331
Source: Bonde DFR (1992) and research review						

All the indicators show that the river pumping costs have a considerable negative impact on the viability of the scheme. The scheme was below the required 9 percent discount rate used in the analysis at that time and therefore should have been justified from considerations other than economic ones. The economic analysis figures could also have been adjusted to make the scheme more viable. The division of responsibilities between DWD and Agritex could have resulted in member departments concentrating on subsystem components in their technological heartland leaving no one to look at the system as a whole. By this time, the emergent reliance on external funding and contractors to implement irrigation designs in Zimbabwe may account for this evidence of the lack of system perceptive, as indicated by lack of control or interface structures to allocate, partition or distribute water across hydraulic blocks.

The name "draghose" for the overhead system installed for field irrigation was popularised by the FAO adviser who contributed most to the design of this system in Zimbabwe. The system has been referred to as the hose-pull system in the USA (Keller and Bleisner 1990). Water is delivered to each 1 ha plot by a network of AC and poly vinyl chloride (PVC) pipes. Each plotholder has a twin valve assembly that provides for setting the pressure of the individual plot and a second to isolate the plot as required. A buried PVC line then runs through the plot centre and has twelve hydrant (garden tap) takeoffs spaced equally at 12m. During operation of the system a farmer holds and lifts the tripod with a single sprinkler mounted at the end and **drags or pulls the hose** from one application position to another.

Each farmer was supplied with 12 hoses of 32 m length and 3/4 inch diameter[4]. Each has two hose clips to connect to the hydrant tape and to a sprinkler mounted on a tripod. Each farmer is expected to irrigate using all 12 sprinklers as long as all the booster pumps are running. There are no guidelines for reducing sprinklers to match reduced pumping capacity for farmers to follow. Theoretically farmers should be able to vary their discharge in multiples of 3 sprinklers for each pump module variation since the pumps are connected in parallel. This ensures that the sprinklers are operating within the design range. In theory this should allow each farmer to grow four crops across their plot that can have different schedules. This is one of the fundamental principles and premises underlying the draghose irrigation system as a concept.

[4] Earlier draghose system designs used the smaller ½ inch diameter hoses because they are lighter and therefore easier for the smallholder farmers to use. The Bonde block C1 original design specified these ½ inch hoses. However with rising electricity costs these schemes designs were reviewed to use bigger ¾ inch diameter hoses. At implementation the Bonde block C1 used ¾ inch hose. The use of large diameter hoses was due to Agritex's own realization that the higher energy costs of an extra six metres of hydraulic pumping head could not be accepted as a permanent convenience cost to farmers.

Each sprinkler is designed to irrigate only in one place for a whole 8 to 10 hours – this is the "normal" irrigation day at peak, a condition referred to by designers and irrigators as the one-shift-per day system in Zimbabwe. Variations to this are two-or three shifts where the same sprinkler is moved to different application positions two or three times a day. This results in a bigger land area irrigated per day but generally to lower depths. Some hop-along systems have been designed where the riser and sprinkler units are moved along the same lateral. This would lessen the lateral movement or dragging-hose (pulling-hose) work but is more capital intensive.

Water mobilisation at the source

The pump station was sited just upstream of the Deure canal intake. There is no structure to control or partition water between the two schemes. Unlike the Deure scheme this intake allows sediment that is mainly sand to enter the pump sump.

Three vertically mounted turbine pumps lift the water some 80m total dynamic head (TDH) through a 3.6km asbestos cement (AC) pipeline into a 5 km concrete lined trapezoidal canal. This passes the water midway through a 1.8 km inverted siphon before discharging into a night storage dam as shown in figure 7.2. At full capacity the operators should run two pumps each discharging 300 $l\ s^{-1}$ with the third as stand by. Each pump is equipped with its own electric switchgear and electronic water meter that records both flow and cumulative discharge. The main problems facing the operators and farmers are siltation of the sump and frequent breakdowns of the pumps as discussed in section 7.5.

The Across-block Distribution System- "*Choice for initial development*"

The Bonde irrigation scheme was planned to have three blocks. The system configuration is given schematically in figure 7.2. The total development was "*divided proportionally according to hectarage among the three blocks*" resulting in block B, which is the single biggest block being apportioned the biggest development cost without removing any extra cost to it due given by the downstream NSD and 3.8 km canal (Bonde design report 1992). A closer examination of the Bonde development plans by the Agritex provincial irrigation team in 1992 revealed that Block B did not really require booster pumping[5]. The gravity head available from the canal or NSD to most fields is as shown in table 7.2.2[6]. For this writer, this reinforces that Block B should have been developed first considering easier technical and economic requirements for operation and maintenance. Its bigger size would also imply increased early benefits. As we see later, the draghose in parts of block A can also operate under the gravity head of the NSD without pumps operating (albeit not that well). This differentiation over the need (or not) for pumps and thus in electricity demands, has confused management and frustrated farmers.

The Bonde Night Storage Dam (NSD)

The NSD directly supplies water to all blocks except block B. The NSD was constructed using earth and has a diameter of 234m, a maximum height of 4m, a full supply water level of 3m and holds 130 000m^3. It takes 5 days to fill using one pump operating 24h at 300 $l\ s^{-1}$. Its function is storage of night flow as at Chakowa and in addition it balances or regulates river

[5] After going through the Bonde FDR and the topographic maps the provincial irrigation team carried at a detailed survey to confirm the head available to block B. They obtained 42m static head sufficient to operate ordinary impact sprinklers. An electricity line had already been installed to pass through a proposed booster pump station.

[6] The MEWRD installed a night storage dam further down the canal as part of their responsibility. This however does not in itself justify the starting of infield designs implementation or operation in any block. A quick appraisal of the operational requirements by Agritex should have pointed to prioritise B block at an early stage.

pump inflow and booster pump outflows over time as well as the different blocks. The water takes 3 hours to travel from the river intake to the NSD assuming a dry/empty conveyance. There is no form of communication between the main intake pumps and the NSD. Pump operators have to cycle or walk up to check the level of water in the NSD. At the intake there are no devices to show the flow situation in the pipeline, canal or NSD. There are no screens to trap trash and save children, animals and other life from being washed into the NSD[7].

Seepage from the NSD recharges shallow wells that are dug downstream in the Bonde river sand bed to water dryland farmers' gardens and cattle. The notion of legality of Bonde gardens has never been considered maybe because they are perceived as utilizing inevitable losses from the NSD. Measurements made during this study gave seepage losses in the range of 36 litres per minute from the NSD at half full supply level. The location of the Agritex houses near the NSD is a cause for concern as this is likely to increase mosquito incidence and malaria risk for this community. Locals fish in the NSD as a pastime or for recreation.

According to the design, blocks C1 and A should have facilities for nurseries to be fed from nursery tanks, but these were only constructed in block A, where they do not function. The tanks appear unwanted and unnecessary. It would have been possible for nurseries to be irrigated direct from the NSD[8]: also farmers in block C1 tend to make nurseries and garden plots" between sprinkler positions as shown in photo 7.2.1.

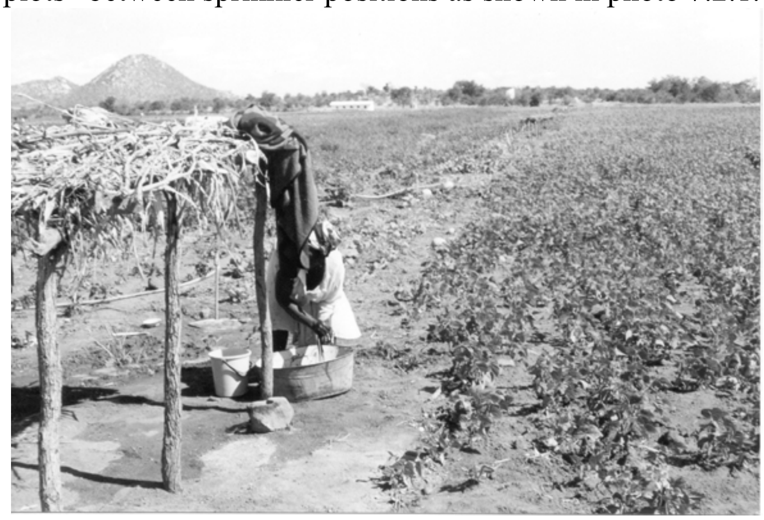

Photo 7.2.1 Convenience and gardening between hydrants at Bonde

The In-block Distribution system

According to report "*the feasibility report for block C1 was probably going to be the basis for the reports for the other blocks A, B and C2*" (Bonde DFR 1992). The designers for block A and C2 did not revisit the scheme feasibility. They focused "on designing" - that is on layouts, hydraulic computations and sizing pipes and pumps only for the draghose and semi-portable application systems. Opportunities for learning and modifying using farmers experiences from completed blocks were lost as they all used the same original planning concept. Modifications were only made based on technical findings during implementation but the fundamentals were never revisited until this study. This section examines the design

[7] In fact a young boy was washed from the canal into the dam while they were playing in the dry canal and water just arrived without warning. His body was only recovered 2 days later. A police sub-aqua unit had to be called to search for the body.

[8] The nurseries could have been directly connected to the main line before the individual pump isolation valves so that they could be irrigated directly from the NSD. Reliable stop-valves with float or other control mechanisms would have been the only additional requirements.

principles for block C1, the first block to be designed, then highlights differences in block A that shape O&M practice.

Block C1 Hydraulic Design

The location of the C1 pump stations was probably dictated by the position of the balancing tank. The land for this block gives a defined slope with a total infield elevation difference of 10 m. The designer decided to position two pump stations next to each other and split the land into two sub-blocks each running down the main slope. Most of the gain in head was expended in friction loss in the parallel supply lines asbestos cement (AC) pipeline running down the two sub-blocks. This created two identical blocks of 50 ha each delivering a limited rigid continuous flow to regular 1 ha plots per farmer, with very similar hydraulic characteristics. This design led to good cross sub-block equity especially in the magnitude of the energy bills[9]. The sub-block IMCs became increasingly aware of this design equity and its dependency on uniformity of operations across the two blocks.

The two identical blocks are hydraulically independent each with its own battery of four operating centrifugal pumps (40kW each) with one standby. However a common power billing station and electricity meter was installed and the block is therefore categorised as a high capacity power consumer. Creation of many billing points is not cost effective as it increases O&M therefore ZESA required specific instructions to bill the independent hydraulic blocks separately which they were not given (ZESA representative, 1999). It was also hydraulically possible to have a lower level block with slightly lower operational costs (due to lower energy requirements) as was later done for blocks A1 and A2.

As discovered in this field research, it is possible for the draghose systems to operate below correct operating pressure when three of these pumps were down, but some pumping must always take place for operation, and the farmers did always worry about paying their bills to keep at least some of their pumps working.

Block A Hydraulic Design–"Sprinklers can operate (or turn) by gravity"

Block A is narrower than block C1 and has a total drop from top to bottom of 30m. Instead of strips running down from the top to bottom with parallel main lines, three levels of blocks were defined. The top most block A1 has its own pump station, with a battery of 4 operational and 1 standby centrifugal units (35kW) and transformer. A main pipe outlet and transformer were requested midway to cater for the middle block A2 with its own battery of 4 operational and 1 standby centrifugal units (35kW). The two lower most blocks (A3&A4) have a common energy metering and bill. Each block has its own of battery of 4 operational and 1 standby centrifugal units (35kW) This resulted in them jointly being high capacity consumers (greater than 300 KVA), at least potentially. However, the farmers in A3 and A4 found, after their pumps were not working, that they could bypass the pumps and still operate their sprinklers (although not that well) using the pressure head from the NSD. The Bonde sprinklers start turning at around 17m and the head difference between the NSD and the A3&A4 pumps is up to 31m, as given in table 7.2.2.

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[9] According to the feasibility and design report "*In order to facilitate the smooth operation of the scheme there will be two sub-blocks of 52 ha each. Each sub-block will operate independently and have its own irrigation management committee, its own pumps and electricity account*"(Bonde FDR 1992)

Table 7.2.2 Summary of design and operational conditions at Bonde

Design /O&M attribute	Block A1	Block A2	Block A3&A4	Block C1.1 & C1.2	Block C2.1 & 2.2.	Block B
Gravity head (m)	6	12	17 to 31	6	12	42
Length of AC pipe m (60cm diameter)	250	750	1250	200	1500	4000
Area (ha) Date completed	40 completed 1998	40 completed 1998	40&40 completed 1998	50&50 completed 1996	50&50 under devt	240 not started
Zesa-rated capacity	Low	Low	High	High	High	NA
Design SOP (kPa)	350	350	350	350	350	NA
Practice SOP (kPa)	350	350	170-250	120-155	NA	NA
No. of pumps operational 07-2000	4 out of 5	4 out of 5	2 out of 5 (two sets)	3 out of 5 (two sets)	NA	NA
No. of broken down pumps 07-2000	1 out of 5	1 out of 5	3 out 5 (two sets)	2 out of 5 (two sets)	NA	NA
Farmers priority	Paying block electricity	Paying block electricity	Securing reliable river supply	Paying block electricity		
Members in main committee July 2000	1out of 10	2 out of 10	5 out of 10	2 out of 10	NA	NA
Practice of night gravity irrigation	Nil	Nil	30 out of 80 farmers	Nil	NA	NA
Extent of salinity-restricted cropping	Major problem by design and operation	Major problem by design and operation	Minor problem by operation	Minor problem by design	NA	NA
Source: field observation, Bonde DFR 1992						

In blocks A1 and A2 there are about 10ha or 10 plots with saline soils that were included in the design. These rarely produce any crops and ponding of water may be seen there although farmers are trying to reclaim and improve soils[10]. Farmers say they must still contribute to electricity payments even if not irrigating. The farmers who operate the pumps (informal pump operators) for the lower blocks A3 and A4 bypasses the pump system and as a result the farmers irrigate at any time as long as there is water in the NSD. This also enables farmers with saline soils in this block to grow and harvest crops "*Tinoibvisa chero ivhu redu rine bare. Tinongoramba tichisiya maspringla aripo*"(We harvest even though we have saline soils. We simply leave our sprinklers running). This is only possible in the lower blocks where there is sufficient head to turn the sprinklers.

[10] Contrary to the saline affected farmers in the upper blocks, one farmer with a saline plot near the A3 and A4 pump houses said she had already invested in her plot by adding manure and would not want to be allocated a plot in another part or block.

According to the local extension staff, farmers from these lower sections of blocks A were increasingly dominating the whole scheme committee. This enabled them to push their agenda on requesting government to provide more reliable water delivery on high priority. They could afford to be rather resistant to other government requests because they could irrigate even when their booster pumps were not working. The next section examines the management support system that was "crafted" to take responsibility for the Bonde scheme.

Paying for electricity and water

The old arrangement was that Agritex and ARDA were paying the DWD for dam maintenance and into a separate account for capital redemption i.e. the loan used to finance the dam construction. The farmers or Agritex were therefore not being charged the blend price of water for this dam water.

The ZINWA proposal was that farmers be charged the blend price of water at the dam like any other farmer. In addition government would pay all river pump electricity costs to ZESA and carry out all river pump maintenance and replacement. They would then recover all the costs from the Bonde farmers in addition to the blend priced water charge. Due to electricity and material cost increases the costs would be periodically reviewed.

As regards the booster pumps Agritex first paid electricity for a pilot 2 years. After this farmers faced steadily increasing electricity charges as prices increased. The farmers keep the records of the payments at their office bearers homes making it difficult to reconstruct the power charges over time for most of the blocks. Block A3 and A4 provided the most comprehensive record as given in table 7.2.3.

Table 7.2.3 Electricity charges for booster pumps at Bonde

Block	**Year**	Amount in Z$.000											
		J	F	M	A	M	J	J	A	S	O	N	D
C1.1	1999										10	11	12
	2000	11		8									
A3&A4*	1999										3		21
A3&A4	2000		25	6	1	3	20	19	72	41	108	32	3
A2							23						
Source: Agritex, farmers and Zesa records *Zesa high capacity point no.2													

In reconstructing some electricity charges and redistributing to farmers it is particularly difficult to deal with high capacity points like that for block A3&A4 due to the significant effect of maximum demand in the calculation of monthly bill. The IMC simply divide any charge by the number of plot holders irrespective of their use or any other circumstance. What is important to them is that everyone has contributed and that the money has been forwarded to Zesa on time. The farmers had not paid any water charges at the time of study.

7.3 THE BONDE PRODUCTION SYSTEM

Crop production practices

The cropping program for Bonde summarised in table 7.3.1 is similar to that of Deure close by.

Basic livelihood crops

The unreliable water delivery significantly affected maize cropping at Bonde. The farmers successfully cropped as early as Deure in the first year of operation only. Since then they have had pump breakdowns and power cuts. Most blocks have subsequently shifted their planting to late in December when the rainfall contribution is significant. This behaviour is similar to the tail-end blocks in Chakowa and is known to be a typical response to unreliable water deliveries (Greenland and Murray-Rust 1986).

Table 7.3.1 Cropping program for Bonde irrigation scheme

Season	Crop	Planting date	Percent area
Summer	Maize	30/10 -15/12	85
	Groundnuts	30/10-15/11	15
Winter	Sugar beans	20/04-6/05	65
	Tomatoes	15/02-20/04	32
	Wheat	15/05	3
Source: field observation			

High fertiliser and labour requirements combined with electricity costs erode viability of wheat as discussed in chapter 5. The two Bonde EWs openly discouraged farmers from growing wheat, challenging them using the gross margin analysis to illustrate its poor financial returns. However a few farmers still grow it as the only alternative for the saline plots.

Some early growers plant long season groundnut varieties and enter the Deure market as wholesalers. Most of the farmers plant short season varieties as a late crop for home consumption and marketing. The other livelihood crops are minor vegetables like rape, onion and cabbage that are grown for nutritional purposes. At Bonde these crops are grown in a row between and hydrants as shown in photo 7.2.1.

Commercial crops

The main commercial crops grown at Bonde are canning tomatoes and ordinary sugar beans sold to general buyers who set up at Deure. Bonde farmers also prefer growing cotton under dryland cultivation where they have bigger areas. Bonde farmers grow two crops of tomatoes like other schemes in the southern part of Manicaland. The first crop of tomatoes is planted in summer after the green maize in January and February. The farmers claim that they have an advantage over surface schemes because sprinklers force them to always adopt good and regular fungicide spraying programs against blight. The successful crop is sold entirely on the table market at lucrative prices.

The Bonde main tomato crop is taken for canning as farmers cannot get direct access to the Deure table market controlled by farmers and the local community who allocate shares to irrigators and non-irrigators. The modalities surrounding the growing and marketing of canning tomato are very similar to Mutema and Musikavanhu[11] (for more sociological study on the growing and marketing of this crop in Tawona see Vijfhuizen, 1998). Women who resell in Mutare and towns like Masvingo buy a fair amount of the late tomato crop directly at the scheme. Some irrigators studied this practice by individually taking the crop to the Mutare wholesale market themselves.

The Bonde bean crop is sold through the Deure depot because there is no secure facility for the buyers to keep the crop before transporting. The road is not suitable for the 30 tonne trucks that are hired to reduce costs. The farmers therefore hire local transport operators who report brisk business. A few farmers transport use cattle drawn carts. The slow pace of demarcating residential stands has been largely responsible for the poor transport arrangements at Bonde.

[11] The same practice is also observed at Chibuwe, Tawona and parts of Nyanyadzi.

7.4 THE BONDE MANAGEMENT SUPPORT SUBSYTEM

The Bonde irrigation scheme was conceived as an FMIS with farmers responsible for all O&M costs. The IMCs were set up with Agritex assistance and trained by head office, province and local Agritex personnel in irrigation management. The IMCs and specific farmers also received training from the contractors in system management - that is pump operation and basic care and sprinkler and pipe network repair and care. The IMCs were expected to work with the water management specialist under the team approach.

Extension Services

The extension officers for Bonde operate from the Deure cluster under the team approach; the general administrative arrangements have been covered in chapter 4. There was one EW per block. However in line with the concept of farmer management, the scheme does not have a complement of Agritex staff employed for infield operation and maintenance works.

Due to the unreliable water supply at Bonde it was not possible to observe extension activities like field days discussed at Deure in chapter 4. However during the water mobilisation meetings (that discussed the delivery of water from the Deure River) the EWs often openly discouraged the cultivation of wheat for viability reasons. The farmers and the local staff required that the water mobilisation issues be settled first before they could entertain secondary issues like water use, scheduling and yield increments just like Mutema (some 16 km away).

Water delivery operational support

Extension agents are not directly involved in water allocation and imposing sanctions as in the neighbouring Deure scheme. This is under the responsibility of farmers through their block and main committees. The farmers do not have a water bailiff or water controller specifically responsible for overseeing water activities in the different hydraulic units or within in the scheme as found elsewhere. The main water operatives at field level are informal pump operators who are mainly volunteers from the hydraulic block. The volunteers are expected to be acceptable to most farmers and the IMCs. They were supposed to be paid by the IMCs from farmers' contributions. However the arrangement was not well followed resulting in most of the original pump operators withdrawing their service and only some dedicated individuals performing the task out of self-interest. The result was that IMCs had no control over the informal pump operators.

Infrastructure maintenance support

There are no Agritex employees directly responsible for maintenance activities at Bonde. The DWD employees only look after the pump river station. The farmers are expected to be responsible for these activities with training and guidance from the local extension agents. These local extension agents get the same training and exposure as the farmers from both the contractor and the irrigation staff from Agritex provincial/central office just after scheme commissioning. They are theoretically supposed to have been familiarised with the technology during implementation where they are given first priority of being employed as unskilled labour. No site-specific maintenance and repair instructions or manual have been prepared. In any case the farmers have neither an office nor storeroom of their own to keep any written material, valuables or security items.

There are no vehicles or stocks of maintenance material at Bonde, just like Musikavanhu, other than tools for the repair of sprinklers. This assumes that farmers will be required to organise and source the equipment without a guideline or they hire or use personal artefacts.

This pressurised sprinkler requires standardisation, monitoring, evaluation and a decision support system. The farmers and local staff are not able to carry out the corrections without the aid of specialists and specialised tools and equipment. However, the DAEO is not well versed with irrigation issues to assist as discussed in chapter 4.

Irrigation Management Committees

Bonde has two layers of Irrigation Management Committees (IMC) that is block committees representing the distribution hydraulic units and a main committee that represents the mobilisation hydraulic unit. The main committee is constituted as a "federation" of the block committees. Farmers in a hydraulic unit or each pump station elect an eight- member block committee members comprising a chairman, a vice-chairman, secretary, treasurer and three committee members. Elections are held annually. Members served for an initial 2 terms but this was later reduced to one year as it was thought be too long. However a person can be retained in the same post or elected to another post for an unspecified number of times. Table 7.4.1 gives a summary of the office bearer in the whole scheme and some blocks that could be recollected. Committee members meet regularly every two weeks especially during the crop planting period or when need arises. Meetings became less frequent and almost disappeared at harvest time.

Farmers using independent pump stations or hydraulic units were required to share electricity bills in some arrangements such as bloc C1.1&C1.2 and A3&A4. Users in each pump station felt disadvantaged thus creating animosity. They therefore made up by either pumping more time or trying to restrict the operations of the other users. Agritex assisted each committee in coming up with a constitution and by–laws. The process involved farmers getting a copy of a neighbouring Deure and Mutema scheme constitutions and by-laws. They would go through them together with their EWs and make relevant changes to fit their own technology, grouping and community.

Table 7.4.1 Summary of IMC office bearers at Bonde

Block	Period	Position					
		Chairman	Vice Chairman	Secretary	Vice Secretary	Treasurer	Committee members
Main (A-C)	1995-2000	L Muchuwa	E Mufundira	E Machando	O Madudze	T Binga	Ms R Kazipa, Z Makiyi
	2000-2003	E Mupinda	C Munirwei	O Madudze	W Hama	Ms. R Kuzipa	B Chipinge
A1& A2	1996-1999	E Mufundira	E Magoso	J Mashava	Anna Mapungwan	K Ziyadum	M Jekete, R Nendang
A3 &A4	1997-1999	M Mutisi	F Mupinda	S Mlambo	O Madudze	Mai Dondow	
A1	1999-2000	E Mufundira	E Mupinda	J Mashava	Evelyn tawonekwa	Ziyaduma	
A2	2000-	E Magoso	S Mupinda	Annah Mapungwana			
C 1	1995-1999	K Nomupanda	J Chishaya	C Bangwayo	D Mugamira	M Fara	M Matsiway, N Bangani
C1	1999-2003	F Komichi		S Chamutsa			
A3							
A4							
Source: Agritex records and field observation							

Table 7.4.2 Attributes of the Irrigation Management Committees at Bonde

Description	Main Committee	Block Committee
Number	1	4
Area	260	40(A1, A2), 80(A3&A4), 100(C1)
No. plotholders	260 (active)	40,40;80;100
Terms of office	1 (started as 2 then reduced)	1 (started as 2 then reduced)
No. Bank accounts	Nil	4 (based on power billing points)
Functions	River intake desilting & river pump and canal maintenance.	Electricity payments, tomato marketing, Booster pump O&M
Operational status	Involved in mobilising support for river pump repairs and electricity payments	4 (C1&A operating, C2&B under development.)
Source: field observation		

The IMCs have no formal employees. As already discussed in chapter 4 with respect to Deure there is no administrative support to the IMCs at either levels. Therefore records and minutes and any "official correspondence" of the committees are kept by the respective secretaries at their homes and transferred to the next office bearer. The Bonde set-up is slightly worse than Musikavanhu in that the farmers in each or any hydraulic unit do not have a meeting place[12]. The main IMC office bearers were the most active during the study period. This may have been influenced by the dominance of the river water mobilisation issues that tended to obscure the contributions of marketing and O&M at lower hydraulic levels. However, also these lower blocks had diverse experiences in their pumping problems and electricity needs. As mentioned earlier, farmers from Block A had a dominant role in the main IMC.

Water Delivery Functions Of IMCs

The objective of Agritex irrigation scheme planners in encouraging the formation of IMCs is to involve farmers in the management of the water delivery system (Bonde FDR 1992). The IMCs, with advice from the two EWs make all water mobilisation decisions related to pumping, abstraction and operation decisions at Bonde. Across block operations like issues related to the main canal are under the main committee but there are no specific individuals who man the canal and observe water levels and communicate with pump operators at the river as observed in Deure. The DWD river pump operators in most cases have to walk up to check the water level in the NSD. The IMC and pump operators decide whether to pump or not but there are no clear monitoring and decision support structures. The operational decisions at the booster pump are also under the farmers block IMC. There is no structure in place that compels IMCs to formally employ, pay or engage in fair labour practice with the operators as discussed in Musikavanhu chapter 6.

Bonde water distribution operations are governed by the pump operation, like Musikavanhu. Generally all individual farmers will irrigate as long as the pumps are running irrespective of the crop. A farmer cannot pass on flow to a neighbour so all they have to do is to find a way of letting the water come out within their own field. There is not much drainage coming from the irrigation due to the farmers' need to control power costs. This therefore essentially structures the system at farmer level unlike in Musikavanhu where the system is structured at group level. Scheduling - just as with Musikavanhu - is not important because there is no earmarking of flow and no facility to claim a rebate for less water use. The system in fact becomes unstable hydraulically if the number of outlets is reduced or exceeded as shown in section 7.5 - just as observed with Musikavanhu. This clearly places both schemes

[12] Meetings are therefore held on the Bonde river bank: government and other officials and respected male members like the Chief Chamutsa, the local councillor and committee members sat on fallen logs. Women each sit on a cloth ("*zambia*") spread on the ground.

in the rigid supply category according to Repogle (1987). However the Bonde system is more rigid than Musikavanhu. The lower blocks A3 and A4 by-pass pumps and operate their system on semi-demand by default that gives them both additional security and additional water allocation.

Block committees play an active role in collection and forwarding electricity payments. Bills were charged on a household basis simply by dividing the total power consumption bill per month with the number of plots irrespective of use. Individual farmers make payments to the treasurer who records the amount paid and date. No invoices or receipts are issued at this level.

Infrastructure Maintenance Roles of IMCs

There are no individuals either locally or externally hired charged with maintenance tasks. There is no schedule of responsibilities on sharing basic tasks. Outside pump houses areas are overgrown with weeds and the inside is dirty[13]. There are no clear financing arrangements for pump and other shared equipment maintenance at both main and block level. The decision and execution of maintenance arrangements at Bonde are just as weak as those at Musikavanhu as discussed in chapter 6. However farmers pay the agreed maintenance charges to their IMCs in the same way as electricity costs.

The main IMC has a rooster on block IMC duties to desilt the river pump station. During peak pumping a group from one pump station walks down and desilts the intake everyday. In each block a household is expected to go down to the river pumps once a week. The NSD and the inverted siphon on the main canal have not yet been desilted due to the short duration of scheme operation. There were no plans yet on how this was to be done.

The Bonde main river pump repair is a problem for the DWD. The field pumps are smaller standard modules on the market and similar to smallholder schemes developed in the same era in other parts of the country. However in table 7.2.1 it is shown that farmers give higher priority to paying energy costs than repairing pump units. Farmers at Bonde block A have taken advantage of lack of maintenance monitoring structures to manage saline fields through by passing pump units that the IMC reported to be non functional to the EW. The farmers did not provide the exact time that the pumps broke down. There is danger that the block IMCs deliberately short-circuit pumps to reduce power bills and avoid maintenance costs.

The pump operators

The river pump operators are DWD employees who were selected at provincial level as reported at Mutema in chapter 5. DWD technicians trained the pump operators in other similar projects before deployment to Bonde. The block pump operators are selected farmer "volunteers" who were trained by Agritex and the contractors in running the booster pump units. Like Musikavanhu they are supposed to hired by the farmers block IMC but in practice they are not paid and therefore end up working as volunteers.

By the time of this study, the organisation of block pump operators was in disarray. It seemed the system-level IMC felt they had no clear authority to summon them for specific purposes. One block chairman complained that one long serving operator organised a relief operator without consulting the block IMC. The other operators had already stopped working because they not received payment of salaries. The two pump operators - one for block A3 pumps and the other for A4 pumps - bypass pumps and take water from the NSD at any time of day and season if available. These pump operators are not being paid but as mentioned earlier they continue to work as 'volunteers'.

[13] A Japanese maintenance expert with a pump company explained to the farmers that the working life of the pumps is likely to be reduced due to dirt getting into the moving parts. The unfortunate part was that there was really nobody permanently responsible as explained here.

Traditional Leadership

The traditional leadership has played several clear roles at Bonde: in the allocation of plots; in acting as a spokesman in the conflict over payment of river-pump electricity bills and in undertaking ritual activities linked with the new site.

Bonde farmers expected the traditional leadership to organise a ritual ceremony for appeasing and informing the land and water owners of the areas about the launch of the scheme. The farmers strongly believed that the problems associated with the operation of the river pumps were caused by this oversight[14]. The Chief also plays a role in adjudicating labour and other disputes. He had to intervene to get outsiders employed, as unskilled labour against the wishes of would-be irrigators and their local councillors who had cited security as a way of excluding them. They probably wanted to exclude them so that they would reduce competition for jobs.

Traditional leaders are the final authority implementers of plot allocation among households of the community residing at Bonde as observed at Deure in chapter 4. Most plots were allocated to Buhera residents who were already living in the development ward. Some limited plots were allocated to applicants resident in the other wards who were keen to resettle in the area. Residents who could not prove their Buhera origins were given short time periods to verify them, process transfers to Buhera or lose plots. Chief Chamutsa openly discourages renting out plots and threatens lazy persons who rent out due to failure to utilise their irrigated plots with re-possession and re-allocation to those on the waiting list.

However the leadership while it is co-operating with Agritex and DWD in the pumped scheme development, clearly and openly expresses its support for the gravity weir and canal option. Chief Chamutsa reminded Agritex during a stalemate between farmers, Agritex and DWD over the operation and maintenance of the river pumps that during planning and design, the farmers were informed that they would only operate and maintain booster pump stations.

Local Government

The councillors and traditional leadership are actually under the same Ministry of local government and National Housing (MLGNH) and both are loosely regarded as local government: at Bonde their responsibilities have some overlap. At scheme level there are personal and minor conflicts that occur as the individuals discharge their duties as appointed traditional leaders and elected councillors. Councillors work through the Buhera council to obtain consensus that defines a people's position.

One such position is the decision to source funds for weir and canal construction for Bonde irrigation scheme when Agritex and DWD forged ahead with development of an electric-powered pumped scheme. The Buhera district council, having agreed to the gravity option, started sourcing funds for canal gravity construction from the Poverty Alleviation Action Programme (PAAP) to realise their own view and objective of a sustainable scheme.

[14] "*Irrigashini inoda kutaurirwa kuvaridzi venyika kuti ifambe zvakanaka. Nhamo dzose dzekufa kwemapombi hadzipere kana tisina kupira kuvadzimu*". After mobilising resources this issue was raised at several meetings and at times the councillor was requested to follow the issue with the Chief. Some believed that the delay was due to the Chief's reluctance to inform the group that first occupied the Chamutsa-Bonde area before the current chieftainship took over control. It is believed that it is only the first occupiers who are allowed to appease the spirits. A similar a complication involving the rain making powers was cited in the Mutema area (Vijfhuizen 1998).

The local district office also "vets" prospective plotholders to ensure that they come and are registered within Buhera district[15].

Local government also plays a role in conflict resolution in situations where the local Chief and councillor are inadequate. One such intervention occurred when the Bonde irrigators stopped Agritex staff and contractors from proceeding with further development until they had satisfactorily improved the reliability level of the main river pumping. The local representatives failed to resolve the issue and the District Administrator (DA) and DAEO had to come down to negotiate with the irrigators to allow work to resume. The DA had to wield his authority and power for the sake of progress, as well as to prevent civil unrest.

Department of Water Development

ZINWA (formerly DWD) is responsible for the operation of the Bonde river pumps. The river pumps are manned by DWD and just like Mutema they have a complement of staff for operation and maintenance. They use facilities that were used by the construction supervision team. They therefore have a good all-weather road, telephone service, domestic water and electricity supply. The river pump operators are motivated and play a leading role in the daily management of the pump station as discussed in section 7.5. The main problem they face is the low budget allocation as summarised in table 7.4.3.

Table 7.4.3 Requirements and actual Allocation for Bonde Pumps to DWD

Year	Estimate Required $ Zim	Actual Allocation $Zim	Percent
1996	2600000	162320	6
1997	3737400	312000	8
1998	3250000	135000	4
1999	-	276400	
2000	-	193600	
Source: DWD (ZINWA) provincial records			

The funds allocated shown in table 7.4.2 were only enough to cover DWD staff salaries and a few basic running costs. There was no provision for regular maintenance. The scheme tended to rely on Agritex allocations meant for the distribution and application subsystem development. Agritex would be compelled to provide funds in order to ensure that the completed and operational systems would delivery water. Inadequate maintenance resulted in poor water deliveries that in turn affected cropping programs as highlighted in the next section.

7.5 BONDE WATER MOBILISATION: OPERATIONAL REALITIES

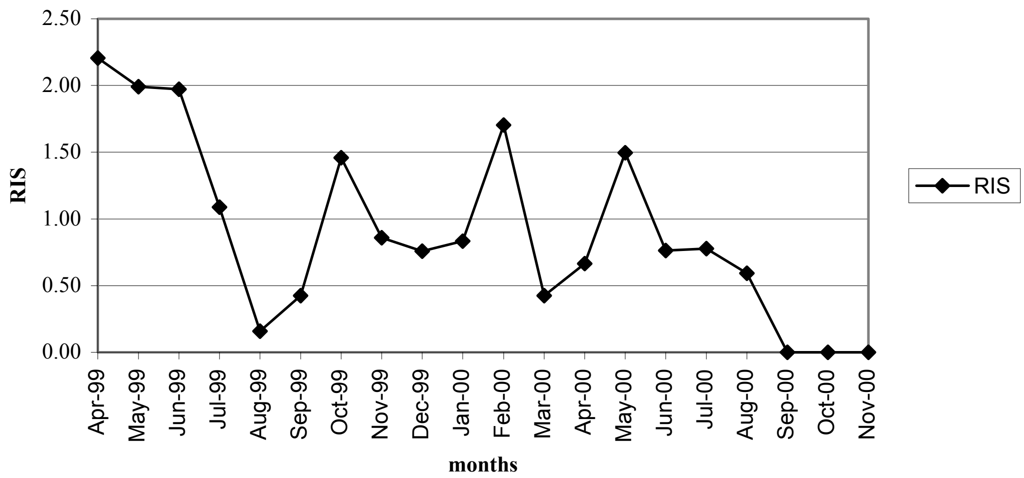
The water delivery practice at Bonde was strongly affected by current and past breakdowns in supply. In 1998 the scheme was not operational from January to June 1998. Electricity had been cut off due to due to a mounting debt. The farmers claimed that they were not able to pay the river-pump electricity bill and were expecting the government to pay. They were preparing to pay the bill for the booster pumps. The DWD had made a few payments just after scheme commissioning and then stopped. They clearly stated that they had no allocation to

[15] All districts universally use the individual's identity number for vetting purposes. In Deure-Bonde four districts Chimanimani, Chipinge, Buhera and Bikita converge within a short distance. Bikita has no irrigation developments in the vicinity and some Bikita registered people say that they have started renting plots and will do so until they get a chance to own a plot in the other districts. They have already taken residence in Bonde.

meet the bill as shown in table 7.4.2. Agritex had no provision for the bill as the scheme was designed as a farmer managed scheme and they expected block A1 farmers (the oldest block operating) to start paying electricity bills from two years after operation began

Water Delivery Performance
The delivery performance of the Bonde scheme was calculated using data recorded by the DWD pump attendants at the river pump station. Figure 7.5.1. shows the relative water supply of the scheme.

Figure 7.5.1 The RIS of Bonde Irrigation scheme 1999-2000



The figure shows that there was adequate water supply during the early winter months from April to June 1999. This was due to Agritex paying the outstanding electricity bills for 1998 using funds viremented from development votes. Agritex had to seek ministerial approval to bail out a number of pumped schemes that had fallen into arrears and had been disconnected[16]. The pumps could supply sufficient water, but only when paid for. Unfortunately the electricity was cut off again in August 1999 resulting in crop loss to late croppers at Bonde.

When electricity was connected, the RIS was high in the month of October 1999 due to water used in pre-ploughing irrigation as well as the low irrigation requirements for the early crop. The CWR increased relative to the water supply and exceeded supply in the period from November to January. The peak in December observed at Bonde is due to the predominance of the livelihood maize crop planted to 85 percent of the area as observed in other smallholder schemes. After maize maturity the scheme experienced another typically high RIS due to both high rainfall and the low cropping during this change period from summer to winter typical of other schemes. The main activity during this time is tomatoes planting as shown in table 7.3.1.

The scheme had a late start in year 2000 due to damage on 23 February 2000 to the electricity panels by cyclone Eline. Although this required only replacement of some electrical relays that had been flooded this took up to mid April for DWD to fix. By that time the neighbouring Deure farmers had already established a 6-week old crop. Priority was

[16] A number of schemes benefited from this arrangement. The major beneficiaries tended to be the large farmer managed schemes notably Bonde, Ngezi, Hama Mavhaire, and Mayorca. Provincial irrigation specialists who were having nightmares with pumped schemes welcomed this with relief.

placed on attending to domestic supplies that had been damaged by the flood due to shortage of electricians in DWD. The farmers then threatened Agritex staff and stopped construction workers from continuing with any development activities in block C2 citing unreliable water supply in the completed blocks C1 and A. Agritex provincial staff contacted the DWD office with little success. The new DAEO had to come down from Buhera with the District Administrator from local government to contain the farmers' anger.

The farmers got a good water delivery during the winter cropping season of year 2000 from the April repairs until August. They were shifting their concern to the reliability of the one pump unit that was operational when electricity **was cut off again** in August due to non-payment. Agritex again dug into the development vote and paid off the bill. By now it was becoming clear that the farmers were not prepared to pay the river pump electricity bill at all. However when electricity was reconnected Agritex expected the farmers to immediately start preparing for the summer crop. The farmer leaders instead ordered the DWD pump attendant to stop pumping. They then called on ZINWA officials and held a meeting to get clarifications on the water charges, and also work out a deal to get one bill for the main river pumps that would include both water and electricity charges. ZINWA officials promised to contact their superiors over the issue. The farmers were meanwhile understandably also pursuing a canal digging strategy through negotiations with some donor. They were reluctant to discuss their strategies with government officials. Agritex could not understand the lack of cropping and they became restless[17]. Agritex called for an urgent meeting to get the farmers views. At the meeting farmers requested both Agritex and ZINWA/DWD to spell out their long-term plans. They clearly stated that they were not prepared to continue cropping unless government made an assurance that they would get a reliable water supply uninterrupted by breakdowns or cutting off.

The ZINWA strategy was that Bonde farmers pay a one combined bill comprising the blend price of water, electricity and maintenance costs for the river pumps that would be higher than the other farmers paying for the blend price of water only. The bill would be reviewed based on the increasing power costs. In return, ZINWA would try to source funds to repair the pumps so they could give a reliable water supply. However the official failed to give an assurance, which the farmers wanted, of no long-term breakdowns. The farmers' major complaint was that government officials were not aware of the exact magnitude and nature of losses that they suffer due to breakdowns of whatever nature. They explained that they lost a lot of fertiliser, chemical and other inputs as well as time and effort when crops fail. In their view officials just come and write-off energy bills and promise to pay another season or so of electricity as though it was the only input to irrigated farming. For that reason farmers had decided not to crop unless firm assurances were made over the water delivery, which they considered a crucial though not exclusive input. The traditional chief, also a farmer at neighbouring Deure, reinforced the farmers' point with the reminder that the idea that farmers would pay electricity costs for the river pumps was never discussed at the launch of the project.

Agritex surveyors had been working with some farmers to considering alternative options and it was increasingly clear that a gravity canal option existed. Agritex therefore felt compelled to make a commitment to meet the main river pump power costs. But it also requested that ZINWA make a direct commitment to ensure that the pumps are kept operating. Besides Agritex promised to continue looking at the canal option and urged

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[17] Word was coming through that a number of schemes were failing to pay energy bills and the situation was discomforting to us in the hierarchy. I admit here that this research seemed to have facilitated open dialogue over the capacity of farmers to meet O&M costs. The fall of the local currency and the power authority's strategy to align power costs to the exchange rate saw the energy costs outpacing the smallholder farmers.

ZINWA to team up in this venture. While the farmers were happy with the deliberations they clearly stated that they wanted firm action from government with respect to assuring a reliable water delivery.

The Maintenance of the Bonde River Pumps

The main maintenance activities at the Bonde river pumps included removal of sand from the sump and repairs of the motors. Farmers from hydraulic or pump stations take turns to desilt the sump using individual tools like shovels and buckets.

De-silting

Sand and trash freely entered the sump up to 1998. Two dedicated pump operators desilted the sump entrance "pad" almost daily to reduce the sand load going into the sump. When the pumps are running during the day the station head or any of his other two assistants closely monitor silt movement and remove trash (mainly leaves). They can show how much the sand drift has moved or drifted each day. They prefer pumping at night because temperatures are lower then but they cannot accurately monitor and remove the sand. Sometimes the Bonde and Deure farmers take turns to desilt the weir. At the time Bonde started irrigating there was real friction between them.

The pumps require at least 300 l s^{-1} for one pump unit. If desilting is not done and discharge goes down to 141 l s^{-1} there is danger of pump cavitation and the pumps are switched off. The pump unit does not seem to be equipped to switch off automatically at low flow. The pump operators should be satisfied by visual estimation that the flow intake exceeds 300 l s^{-1} before starting to pump.

According to the DWD Mutare engineers the problem was very bad before they installed a second trash screen. There are now two trash screens in series that hold back sand and trash: the second screen added later is at the sump and weir base interface and so is easier to access and stream velocity is there much less. This screen also holds back sand. At the as-designed screen only rash is held back because the flow velocity is high enough to take in sand. The layout of the weir and pump station is shown schematically in figure 7.5.2. Some consultants have suggested changes to this layout in order to facilitate sand exclusion. Preliminary studies by a Dutch civil engineering consultant and a visit by some Japanese engineers both led to suggestions to redirect flow so as to reduce sand accumulation at the pump. These in my view are good attempts at addressing the visible symptoms.

Revisiting the siltation problem - a design problematic

The siltation problem at Bonde has operational requirements, is a maintenance issue and has required design interventions that have been proposed, interpreted and are expected by different actors. The local DWD office addressed the leaves and trash problem successfully by installing a second screen. They then tackled bed-load (that is mainly sand) going into the sump and causing most of the impeller abrasion shown in photo 7.5.1. They made a concrete pad and stabilised the upstream bank with vertiver grass as shown in fig. 7.5.2. However according to some they managed to do two other things. (a) They created an ideal site for deposition of sand and any bedload at the entrance of both the pump sump and the canal. This was due to the fact that they trained the main river flow/stream further away from the pump sump and the weir outlet. (b) In order to ensure that it never comes this way they then stabilised the banks to ensure no secondary stream will interfere with the sand and sediment collection process[18].

[18] Theoretically pumping or abstraction should be aimed at the main stream that has minimum sediment load.

Photo 7.5.1 Farmers desilting the pump intake at Bonde

By stabilising the banks it means even the high floods attributed to the cyclone cannot take away the "previous deposits" in front of the sump and canal intake. The Deure farmers did notice this as they said that from their long history of cleaning the weir they had never seen such high levels of siltation. They therefore said this concrete pad had made things worse.

According to them this was one reason “them” should never have used a common weir for the two schemes[19]. "*Zvaitwa apa zvabva zvatoita kuti jecha riungane pamuromo pemugero wedu. Dai vakangoita zvavo kwavo uko vakasiya pedu pakadaro. Ndosaka tainge tisingade kuti tidyidzane nezvemapombi avo aya*".

In fact the local ruling political party central committee member admitted just after the floods that he at one time got very cross with the then DWD technician in-charge of Bonde construction. The technician had deliberately closed the canal with stop logs just after the entrance in order to divert more water for pump tests. He had done this without consulting the Deure farmers who got very cross when they discovered that he had tampered with canal flow.

Widening of the section with the concrete pad was done because of the shortage to the pumps, as most water went down the canal. When the initial design was conceived, and during the initial operation, the water would be trained along the weir at times of low flow with the help of sand bags. At the entrance the water would be divided without any proportioning device to allow the pumps and canal to run simultaneously. However the pump operators would normally find insufficient flow and would thus either close Deure canal - and risk farmers' anger - or switch off the Bonde pumps by day and operate at night. The Deure canal was choking the pump sump. It was probably an attempt to address that choking that gave rise to the opening-up strategy. The damming effect created a pool that is technically necessary for large pumps to avoid cavitation and it reduced the "fights for water" between Bonde pump operators and Deure farmers. However at the stream entrance of the “dam” the sediment deposits and closes off the pool or “dam” from the main flow. This effectively interferes with Deure canal flow that was designed to take in sediment and then flush it out by lowering the twin sluice gates. The flow is therefore returned to the river as summer flood return flow as shown in figure 7.5.2.

[19] The Deure farmers constantly refer to “them” which probably means the designers and authorities. They tend to emphasis their non-involvement or lack of consultation in the decision making process.

There is a need to establish transparent procedures and regulations to inform and direct sharing of flow between the two schemes. Sharing of water between schemes is still new in Zimbabwe and there is need to consult widely and internationally to find sustainable solutions.

Establishing the design flood for pump stations

The Bonde main pump house is located in a high flood risk zone. A maximum flood of 239 $m^3 s^{-1}$ recorded on 7/01/1996 at station E118 Deure-Chisurgwe flume upstream flooded the pump house. The panels were flooded again up 1.5 m by floods resulting from cyclone Eline on 23/02/2000. This flood is reported to be a 1 in 60 year flood.

The answer from DWD was simply to propose to raise the panels at Bonde by 1.5 m, and not to relate this with any technical design norm. There is still no clear answer in manuals, nor from external programme staff questioned at the time.

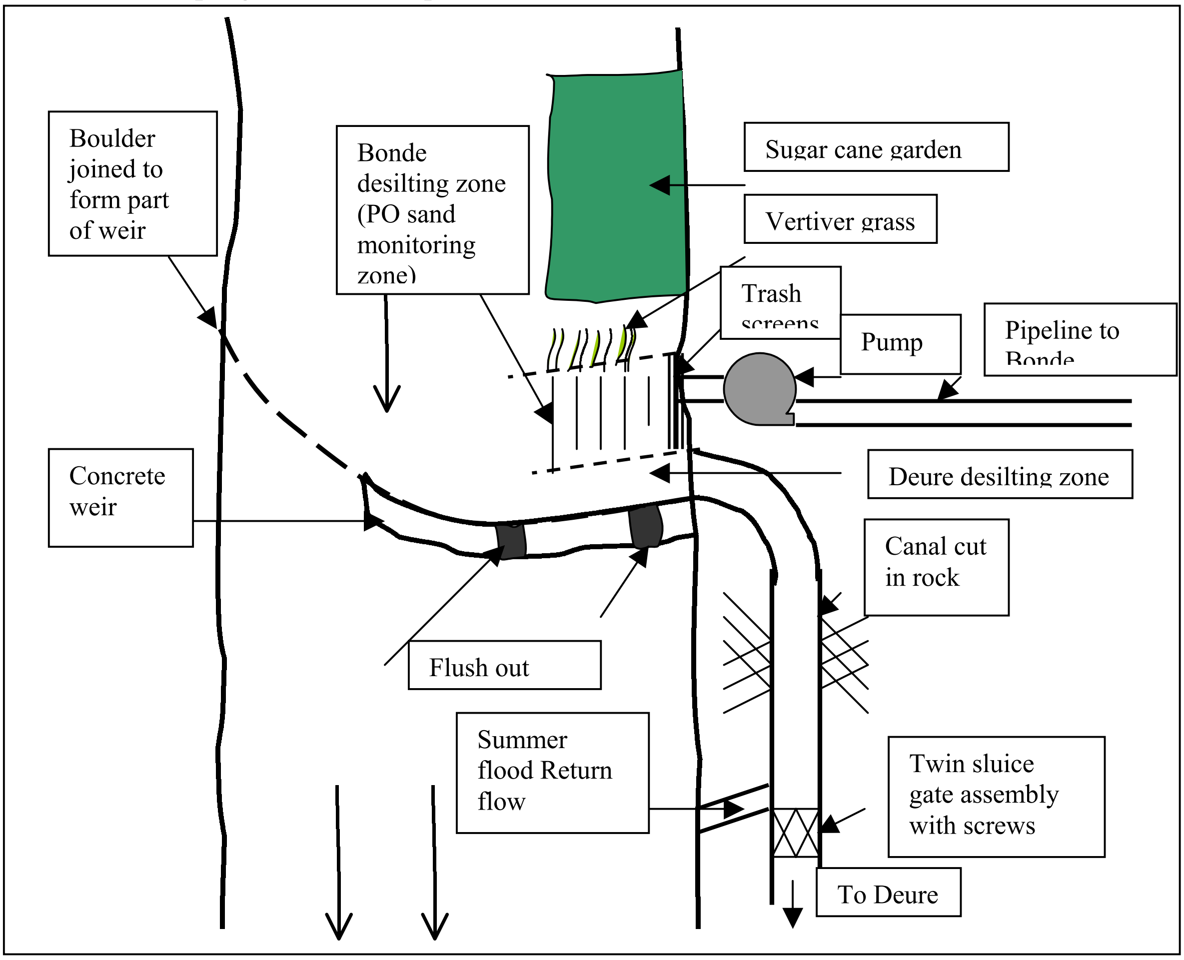

Fig 7.5.2: Schematic Plan View of Devure Weir and Bonde Pump Station

Pump Breakdowns- *Vertical Mounted motors - Fitters Dilemma*

Besides the electricity cuts the other major contributor to unreliability of supply water to Bonde has been the frequent breakdown of the river pumps. Although the river pumps started operating in 1996 they have not run for one full year without a major breakdown. Records show that the units did not breakdown during the winter seasons of 1997, 1999 and 2000. Currently only one unit is installed and operational. The other two units have never worked satisfactorily until now. The pump and motor units have frequently been removed and reinstalled after testing, but only thanks to the gantry unit that was put in as an afterthought.

When the pump house was built there was no facility to lift the pump unit[20].

Photo 7.5.2 Vertically mounted motor at Bonde

The pump assembly, which has a motor vertically mounted above a vertical pump as shown in photo 7.5.2, requires both a crane to lift and a fully qualified fitter and turner to mount. It is always necessary to properly align the pump-motor units to avoid vibration.

According to the workshop foreman and senior technician the two pumps at the edges show little vibration when properly fitted. The central pump unit vibrates very much. They will most likely vibrate and wear away the wearing course in no time as shown in photo 7.5.3. This is taking place very quickly at least a due to the sand that comes with the water. It was estimated that new wearing course is required every four pumping seasons. The workshop is trying to find a local filler material that can be used to replace the wearing course as a cost cutting measure.

Photo 7.5.3 The Bonde pump wearing accelerated by sand in water

The guarantee for the Bonde pump units expired or lapsed on a time basis. It is understood that this was due to manufacturer's foreign currency and clearing problems[21]. When the pumps were finally installed and had problems both the manufacturer and contractor could not be held contractually responsible for defects.

According to DWD staff responsible for operating Bonde Station, the pump unit requires that a fully qualified electrician has to be frequently called to site to ensure that all the wiring is done properly after the frequent tests and re-fittings. Some less qualified personnel had led to the burning of wires and motors. The DWD senior technician in Mutare responsible for the irrigation pumps has to be present at virtually all such installations to sanction each event. Admittedly this makes the technology really "high-tech" and Agritex

[20] It was only after hiring cranes from Harare several times during repairs that the DWDengineer responsible in Mutare designed and installed the crane over the pump house. Each time they use the crane they have to take out some roofing sheets (Pazvakavambwa 1995).

[21] The DWD Head Office designs engineers say that South African pumps were bought and imported. They were then held at customs for a full year because of clearance problems**.** These pumps were therefore orphaned at birth to use Speelman's terminology (Speelman 1990).

local personnel, the IMC and farmers have to simply observe and wait for the signal to desilt or start pumping at the booster units. To these groups (Local Agritex and farmers) the problem is not so much the technology per se but its unreliability. This situation clearly highlights the skills requirements of technologies. The large pumps are engineered to be more efficient and probably more reliable than smaller units. However their care and maintenance requires highly qualified and specialised technicians. There remains an engineer-technologist interface that has been noticed elsewhere (Ferguson 1993)

These issues were clearly spelt out by the managing director of Johnson Pumps and chairman of Irrigation Institute of Zimbabwe in March 2001 at a seminar held to discuss design problems affecting smallholder farmers. In industry, small units were preferred because they can have stand-by modules and there are local appropriate workshops specialised in repairs in case of breakdown. Use of small units that can be bought from stocks available in the local industry is preferred to importing large pumps. The long-serving pump modules at both Tawona and Chibuwe are small and locally supplied. The problem is that due to the distance and location of farms or irrigation schemes backup from qualified personnel is not a constant. **Pump technologists in Zimbabwe thus tend to prioritise maintenance concerns before technical efficiency.**

7.6 DISTRIBUTION AND APPLICATION PRACTICES

Distribution and Application Performance

As already discussed, problems with the water mobilisation hindered a study of the distribution and application subsystem at Bonde scheme. However, Table 7.6.1 shows some uniformity figures obtained in block C1 in June 2000. Plots were selected by first structuring to cater for the upper and lower portions of each pump station block. Plot numbers were then selected at random by picking from a hat.

Table 7.6.1 Christiansen's uniformity coefficients obtained in some plots at Bonde block C1.

Plot number	Sprinkler operating Pressure (kPa)	Christiansen Uniformity Coefficients (CU%)
C1.1 no.1	150	32.7
C1.2 no.23	130	25.4
C1.1 no.39	155	47
C1.2 no.42	140	32.3
C1.2 no.1	120	14.7
Source: Field observation		

The Christiansen's uniformity coefficients were obtained using the catch can method as detailed for Mpudzi. The low figures are attributed to both the low pump pressures, leakages, wind effect and the resulting distortion of the spray that leads to less water falling in the drier parts (Wilson 1974, pp3).

Electricity bills, pump maintenance, and sprinkler uniformity

With this study, some farmers then revealed that two of their five booster pumps were not functional. They were therefore operating only three pumps without a standby. They seemed unaware of the problems this could cause of sprinkler low pressure. When the rest of the farmers heard about the tests probably from the local EWs they organised a meeting and agreed to repair the two that were not working. They engaged the Mutare based company that installed the pumps to effect repairs on their account. A second uniformity check could not be carried out because electricity at the main river pumps was cut off in August 2000 leading to lack of water delivery as shown in figure 7.5.1. This led to crop loss as Bonde farmers had planted late due to late repair of river pumps after cyclone Eline damage. This also led to some animosity to the researcher and assistant for drawing attention to a problem on which money was then "wasted" [22].

The low CU values shown in table 7.6.1 can be largely attributed to low pressure due to the pump breakdown. Poor distribution at the boundaries was particularly noted in plot C.1.2 number 1 near the pump house. The bean crop near the edges was showing visible signs of wilting that described circles of stress at the edges of the spray. This particular meticulous farmer and his wife had clearly marked and put pegs to define the path of the water filled hose as it drags to the precisely pegged sprinkler tripod position. They dared not move the position an inch. They were not aware of the use of the extra hose length in compensating for the wind effect. Therefore the crops at the edges suffered stress and yet the 2m extra hose length was nicely and meticulously aligned along the draghose path. The other farmers on the other hand had sprinklers positioned all over the field.

Some farmers moved three sprinklers side by side at 12m apart up and down the same six positions to overlap and effectively irrigate in a quarter of the 1 ha plot as proposed in the design. The farmers at Bonde have largely followed these recommended sprinkler movements during the irrigation of major crops like maize and beans. Different practices that deviate from the norm have been observed for crops that have staggered planting and small and variable areas like tomatoes, vegetables, potatoes, groundnuts and wheat. The set times and next position are entirely at the farmers discretion and individual sprinklers operate in different locations with no path or pattern. Few EWs know how to give advice for draghose.

Farmers always irrigate as long as the pumps are running because there are no guidelines to follow that allow a farmer to demand water as required by their individual schedule. There are no guidelines or facilities for the operator to supply water to a limited number of users and relate this to their electricity payments. This is exactly the reason why the system defies the design objective of meeting requirements of "CROPWAT" because the farmers or local EWs have no capacity to meet the individual crop-scheduling objective.

Leakages at the hose clips

Leakages were mainly due to the hose clips and their replacement strategies. Hose clips used to secure the hose to the hydrant and riser fail very quickly. Both the wire type of clip and the grooved metal type have been tried and neither have performed well. Farmers have therefore turned to the use of the common rubber strings or the natural tree bark. In order to ensure or reduce leakage some plastic strip is also tied round before fastening with rubber or tree bark. The natural tree bark cannot sustain the operating pressure of the sprinklers and therefore it is not effective. Rubber though effective and common easily gets worn out and breaks requiring frequent replacement[23]. Some Bonde farmers have tried to use the heavier mining hose

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[22] The farmers had been paying electricity for a year and they were aware of the pump problems. The majority preferred that they keep their money to pay for electricity. The decision to eventually get the pumps repaired was only made after the EW informed them that we had noted that the system was operating under low pressure. Unfortunately just months after they had repaired their pumps the night storage dam went empty due to a power cut at the main river pumps as a result of non-payment. The bitterness of having repaired the pumps, planted a late crop and now they loss everything was tearing the farmers apart and therefore they refused to plant the summer crop without hard talk and govt. assurances as discussed in section 7.5. This researcher's position was compromised because the looking into sprinkler uniformities had persuaded them to repair the low priority booster pumps- so their own conservative judgement was proving right.

[23] Some schemes like Mpudzi were earlier designed to use turf hydrants instead of hydrant taps. The rubber seal was pron to tampering and damage leading to malfunctioning and leaking resulting in them being replaced by hydrant taps. The current position is that the hydrant taps seem to be our best option.

instead of reinforced plastic. It provides a better seal with hose clips than plastic. Mining hose is not readily available on the market, and its economic life in draghose systems is unknown.

Wind effects

Farmers and EW are acutely aware of the effect of wind on the distribution of sprinklers, but they do not understand the requirements for correcting the effects. They were not willing to undertake recording of wind data on a sustained basis, and EWs said they were not briefed to undertake such measurements under their team approach. The few records of wind taken in the season of year 2000 show speeds in the range of 14 km h^{-1}. A design maximum wind speed of 8.14 km h^{-1} was used based on the agro-meteorological data handbook. At times these winds seriously distort distribution at Bonde. One can stand 1 to 2m from the sprinkler and get no drop of water from the spray. The Bonde farmers have not improvised much to correct distribution problems.

A 3mm nozzle sprinkler was adopted with a design head or operating pressure of 35m (350kPa). According to the uniformity tests done on this nozzle at the ZITC this nozzle sprinkler works best at 25m (250kPa) head. Pilditch recommended an operating pressure of the 3 mm nozzle sprinkler at 260kPa (Pilditch 1977, pp9). Wilson's recommended operating range for the 3 and 3.5 mm nozzle sprinkler is between 240 to 300kPa (Wilson 1974, pp7). Calculation of sprinkler spray coarseness index for the 3 mm nozzle sprinkler at 300kPa and 350kPa using the method given in Keller and Bliesner confirm that the spray is fine (Keller and Bliesner 1990, pp 99 108-112)[24]. Fine sprays have high drift and evaporation losses that can be as high as 8 percent for conditions in Bonde. Farmers do not disconnect rise extensions for short crops like beans and tomatoes. This practice increases losses due to wind drift and evaporation (Keller and Bleisner 107-108).

The practice of caring for infield equipment at Bonde

Some of the highlights in the farmers practice of caring for hosepipes, tripods and sprinklers are given below.

Storage of hose pipes – in arid conditions

The majority of farmers do not take their hoses and sprinklers home after irrigation as they irrigate on most days. Good farmers however take hoses and sprinklers home after season or when a break in irrigation is anticipated. According to the original hoses design concept the hose-sprinkler units are supposed to be individually kept (Makadho 1990, pp7). Those left in the field for long periods tend to discolour and crack. Transparent hoses in Bonde promote growth of algae in the hose if it is left wet in the sun. The current design recommendation specifies for dark hoses for use in the arid areas like Bonde.

Sprinklers and tripods

Tripods and sprinklers at Bonde have not received much maintenance attention to date. The few sprinklers that are different are due to innovators trying other marketed products like plastic and part-cycle sprinklers. The farmers have generally not replaced sprinklers, as at Mpudzi, for two major reasons. First the higher down-time experienced due to the main river pump breakdowns or power cuts have reduced the relative operation period of Bonde compared to Mpudzi sprinklers. Secondly the Bonde system was designed with an allocation of 12 sprinklers per ha having one shift per day compared to Mpudzi with 6 sprinkler per ha

[24] The coarseness index (CI) based on work by Frost and Schawalen(1955). It estimates the effective portion of applied water that reaches the soil-plant surface (Re). When CI >17 the spray is fine and for CI<7 the spray is coarse. The Re is interpolated from the range of values of CI, wind and evapotransipiration data. Calculations using this approach are given in chapter 8.

and 2 shifts per day[25].

The draghose system at Bonde is functioning well as a method of applying water in general. Technically however the system has low uniformity due to low pressures due to pump breakdowns, leakages and farmers deliberately by passing the technology to save on costs. The maintenance requirements of the system have been "moderated " by the high down of the river pumps and electricity cuts.

7.7 DISCUSSION AND CONCLUSIONS

Bonde represented several brave new elements of the technological trajectory in use of pressurised equipment offering flexibility for cultivation practices in the field, in a large-scale system (for Zimbabwe), and its farmer management. Yet in reality the needs of the system and its leverage were never thought through. What appears is segregated technical engineering of artefacts to provide a WDSS to a community with an unrealistic agenda for change. The developers assumed that farmers would spontaneously provide an appropriate MSSS that would ensure objectives centring on high water efficiency through practising the modern concepts of CWR based scheduling and individual flexible cropping choices. In fact the researcher found a community using atomised institutional arrangements and uncoordinated and unreliable water delivery that was being fuelled by electricity cuts and pump breakdowns. An analysis of the problems at the river pumps reveals pump selection was inappropriate and there were several design lacunae relating to managing silt, the pump repair options and feasibility of mobilising energy costs.

According to the feasibility study, "*the scheme was recommended considering social factors.*" (Bonde DFR 1992). However by 1998 (just two years after start-up) the Bonde farmers and the Buhera community had prioritised the construction of a canal to supply water to the Bonde scheme. The researcher was shown the proposed abstraction site by the former councillor in 1998, who even left his election campaign team to do this, along with the then chairman of the IMC and extension worker for the Bonde C1 block and some interested farmers. It was in a solid rock portion on a major curve of the Deure River. They explained that this site was identified a long time ago when the scheme was first conceived.

According to the Local Agritex extension staff, the community had in 1997 approached the Poverty Alleviation Programme (PAAP) seeking for Z$30 million to help them start on their canal construction venture[26]. It is understood that they made an undertaking to provide labour for digging the canal, as done long ago at Deure.

People see feasible leverage locally for weir and gravity canal systems, and I think this is where to foster organic learning and build internal institutional memory for the smallholder irrigation sector. Within the Agritex knowledge base, interests in distribution and application technologies and use of draghose technologies obscured the water mobilisation issues at Bonde, which were never thought properly about in the overall design concept. This led to a failure to think adequately about an MSSS that could leverage the WDSS, to cover for shortfalls in design. The farmers as a result tend to then consider the WDSS as a government system at Bonde to the extent of expecting guarantees and compensation against crop failure

[25]That is each individual sprinkler irrigates in one physical location or position only for a whole day or part thereof and is only changed/ shifted or relocated to another position once in that day in preparation for the following day's irrigation for post irrigation shift practice. Alternatively the individual sprinkler is shifted early morning to a location for that day's irrigation and the water delivery system will be switched off with the individual sprinklers left in their physical location overnight for an early morning or pre-irrigation shift practice.

[26] The exchange rate was then about 1U$ to 26 Z$.

or loss of input due to pump breakdowns or power cuts. Draghose is viable however, as will be seen in the chapter 8 study of Mpudzi - a gravity system with more secure and reasonably stable mobilisation and distribution and less management challenges.

Pump operation and maintenance

Lack of water delivery security mainly due to pump closure clearly dominated the Bonde farmers' agenda, and masked the benefits of source stabilisation due to the Ruti dam that was seen at Deure. Bonde farmers lost all winter crops in the study period for reasons related to power cuts due to none payment in 1998, 1999 and 2000 as well as delays in planting in 1998 and 2000. The delay in planting in year 2000 was due to delayed repairs to motors after flooding. The study ended with farmers taking a hostile approach towards the developers by stopping further implementation. They ordered DWD pump operators not to pump for the summer year 2000 cropping season before getting guarantees that delivery would not stop during the cropping season from operation and maintenance problems. They started to seek direct negotiations with ZINWA over service charges. Until now, energy is not considered as a resource like land, water, labour and capital (Irrigation Manual 1994, pp 4,174-175). This is proving to be a fundamental conceptual shortfall in smallholder irrigation development in Zimbabwe that requires immediate attention. **The new designer, when choosing technology, needs to start by appreciating that energy is a resource that needs to be optimised in smallholder irrigation development programs in Zimbabwe - and other countries that rely on substantial power imports.**

The pump maintenance problematic being experienced at Bonde is already haunting farmers and agencies in Mutema and Musikavanhu. Pumps with no local backup and requiring substantial amounts of foreign currency for sustained operation should be discouraged. Alternatively local industrial capacity needs to be supported to sustain the artefacts as reliable components of the water delivery system. The leverage necessary seems to be outside the scope of management actors for the Zimbabwean schemes studied.

Desilting for large pumps working with high silt water / rivers

Siltation problems at pump intakes in Zimbabwe are not restricted to Bonde alone. However, this study emphasises how in pump systems we find that farmers seek a technical solution while water engineers or pump experts encourage farmers to take responsibility for desilting as part of participation. There are no easy solutions to these siltation problems as is increasingly becoming clear in the larger smallholder schemes. Older river pumping schemes like Tawona and Chibuwe seem to be coping with farmers and DWD pump operators constantly fighting the "silt war" despite the constant fear of crocodiles. Farmers have learnt to work or operate with these problems, but have also had a support system that has helped to coordinate work with them (although this support level has declined). Apart from the lack of organised support, Bonde however faces other dilemmas. Bonde scheme is some 10 km from the main pump station. The need for farmers to constantly desilt requires that they need a team that is frequently coming down to the intake to help the pump operators. Water releases from the Ruti Dam come down with flashes of sediment that add to the desilting requirement. The Deure canal next to it has a silt excluder that requires only one or two operators, and that constantly releases sediment unless the flow is very low when it is closed off. Perhaps also newer farmers have tended to underestimate the labour input and perseverance required to fight the "silt war", and are therefore less prepared to do it when their other equipment, like the draghose, is highlighted as more efficient and "modern".

The Bonde problems of pump choice and siltation have not yet been internalised by designers or international experts, as seen in the new Nyakomba smallholder scheme. The Japanese government provided a grant to the government of Zimbabwe and construction of Nyakomba irrigation scheme from the 1990s to 2002. The scheme takes water from the Gairezi River. Three pump stations have been constructed to serve three blocks of land. Each is equipped with horizontally mounted pumps supplied by a Japanese pump manufacturer. A pump expert will be dispatched for 1 month in a year from 2000 to consider the pump maintenance requirement for Japanese assisted schemes and other schemes in Zimbabwe. This facility was provided for at Nyakomba. Specific boreholes had to be drilled to supply clean water for shaft lubrication. A similar suggestion has been echoed for the Nenhowe / Nyanyadzi pumps. In a meeting between farmers, Agritex and a Japanese pump expert and JICA officials, farmers constantly referred to the silt problem and advocated for a technical solution. However from the Japanese expert and JICA officials response it became clear they thought the solution lay mainly in the farmers' organisation for desilting.

Draghose systems

This chapter shows that draghose systems to discharge water to crops work in general. However the level of terotechnology results in poor uniformity thereby reducing their effectiveness and efficiency as ways of improving farmers water management at field level. The leverage lies in farmers being able to appreciate the designers objectives in choosing the technology. This congruency and convergence can only be initiated after the security and reliability issues are addressed at Bonde.

The Bonde FMIS

The case study shows that developing FMIS at Bonde is a panacea not a reality. The farmers and local agencies they work with need time to understand and build strength through do-able tasks. They both need to recognise the concept of FMIS, internalise it and own it so that they can set their own objectives and goals. This requires a process of aligning them through learning and vision sharing. They need to be guided in working with or making choices regarding the work of multiple agencies.

9 THE OUTCOMES OF TECHNOLOGY CHOICES

9.1 INTRODUCTION

Preceding chapters have shown the range of irrigation concepts in the technological trajectory of smallholder irrigation in Zimbabwe. The two dominant technological paradigms have been gravity distribution systems with lined canals, moving into pumped overhead systems, with hybrids also between the two. The older institutional paradigm has been one of strict state agency control, with both technological paradigms cut across by the new institutional paradigm of turnover to farmer management.

This chapter makes a comparative review of key differences in system management practices and how these shape operations and maintenance, system performance, but also outcomes in production options. Thus the chapter is structured in relation to the sub-questions of the research given in Chapter One. In this way, one can see how, and whether, technologies make a difference in water supply and cropping outcomes. The chapter concludes with a summary of key areas of farmers' concern, and their actions in the face of the problems left by Zimbabwe's technology trajectory, and its choices in water supply systems and the management systems to run them.

9.2 THE POLICIES UNDERLYING IRRIGATION CONCEPTS

Manzungu (1997) traces the evolution of smallholder irrigation policy[1] objectives from 1912 to 1991 and highlights the pervasive thought of enhanced food security for smallholder African farmers. The key other areas of emphasis have been the level of government involvement in managing, financing of schemes, resettlement of blacks from commercial farming zones, before the racial overtones that have punctured events in this sub-sector. Shortly after Independence, Mupawose (1984) defined an
" *ideal policy for irrigation development as one that will contribute most to food production, maximize economic returns, achieve an equitable distribution of productive resources and enhance the capability of the agricultural sector to minimize the adverse effects of seasonal droughts which are common in Zimbabwe".* He thought importation of food should only be considered as a last resort as it requires foreign currency that is always limited. Maize the staple food crop is also very sensitive to drought. For Mupawose "*Irrigation is the only meaningful method to ensure ourselves against the hazards of the weather*" (Mupawose pp i-iii, xii in Blackie 1984)[2]. To older policy-makers, unreliable rainfall, and the incidence of mid-season droughts are the single most critical uncertainty for farmers in Zimbabwe, giving the need for irrigation, but also shaping risks in the provision of irrigation water.

At the micro-economic level, other later expectations of irrigation were that irrigation would:

- Enable double cropping (Manzungu 1999, 23);
- Produce higher yields as compared to dryland cultivation;
- Increase food security in marginal areas (Pazvakavambwa, pp 421 and Rukuni, pp 379 in Blackie 1984), raise farm income and create employment;
- Earn foreign currency through exports and import substitution;

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[1] I adopt Manzungu's definition of policy as a 'statement of intent concerning irrigation development enunciated by the state through its various institutions (Manzungu, 1999,pp25)

[2] Mupawose is former permanent secretary of the Ministry of Agriculture.

- Facilitate adoption of improved farming techniques and establishment of an irrigation based industry (Manzungu 1999, pp 23) and
- Foster rural development (Rukuni, 1984 pp 379).

However, systematic policy instruments have not always been there to achieve these aims, (Manzungu 1999, pp26-27), especially since this broader and more complex list of objectives were present.

As Chapter 2 stated, from 1985, wider government policies emphasised reduction in subsidies and greater farmer participation. The Zimbabwe Agricultural policy of 1995-2020 informed by the FAO sponsored Policy and Strategy Document of 1994 introduces many new concerns of environment sustainability, equity and efficiency of water use, and water pricing besides the recurrent institutional issues and the drought mitigation roles (Manzungu 1999, pp26). These have also come at a time of greater experimentation with more sophisticated technologies, as Chapter 2 showed. From the mid-1980's, new contacts with bilateral aid multilateral agencies brought in new scientific and technical interests, that we see driving interests in pressurised systems, but also expansion of irrigation area into locations where pumping technology was needed.

According to Carter elaborating from Underhill (1983) *"Small scale irrigation is a management concept rather than a matter of size as such"* (Carter and Kay pp 370 in Blackie 1984). However, Pazvakavambwa in 1984 argued that while smallholder schemes had provided food security in low rainfall areas they had lacked a *"parallel development of the farmer to enable a complete take-over of the schemes through a self-sustained management system"*[3]. It was on this premise that the Irrigation Management Committees were formed as detailed in chapter 2. Pazvakavambwa summarised the objectives of their formation as: to enhance farmer participation; to prepare farmers for management take-over; create a responsible attitude and sense of belonging; to introduce self-regulatory and self-disciplining machinery; to cultivate rational decision making and planning and ensure success in operation and maintenance of irrigation system after government withdrawal (Pazvakavambwa 1984, pp424).

Recurring problems facing committees in 1984 were listed as: lack of credibility; lack of incentives for committee members; lack of legal framework and status; and lack of institutional support (Pazvakavambwa, 1984 pp 424-425). The lesson from this study is that the old schemes are still operating as much as possible under the older policy framework of livelihood crops and state control. The new schemes are being forced to operate under the new economically driven prescription of IMT as given in the FAO sponsored policies from 1994. Another lesson from this study is that the problems identified by Pazvakavambwa (1984) still exist, except where farmers themselves have acted to build their control and legitimacy. The real intervention of the state has remained insufficient to provide legal status and management capacity despite the rhetoric, and that farmers have had to struggle hard to gain control over technology that has been applied supposedly to solve some of their water supply and management problems.

[3] The terms 'small-scale' and 'smallholder' have often been used interchangeably in Zimbabwe to refer to the same farmers and irrigation schemes. In fact the critical concern is that they are systems serving smallholder, which are also small in ways that affect management needs but also financial costs. Vincent (2003) notes that smallholders have small plots for subsistence and some commercial crops, and that smallholder systems have often had a strong degree of state/public support and direction in their creation.

9.3 PRODUCTION SYSTEMS FROM IRRIGATION

The crops grown at the six schemes can broadly be classified as summer and winter crops. Summer crops are generally crops planted after the cold months of June and July and generally utilise rainfall during all or part of their growing season. Winter crops are grown after or at the tail end of the rainy season and are subjected to the cold weather during part or all of their growing season. The main crops grown are shown in table 9.3.1. The crop programs are still dynamic in new schemes, especially at Musikavanhu and Mpudzi where marketing arrangements are still being tried. The changes in irrigation technology were expected to bring more flexibility into irrigation, to support crop diversity and more commercialised cropping. However, with the exception of Mpudzi we see few differences in cropping between the systems, except around the relative balance of one or two crops. Cropping at Deure and Bonde is almost identical, despite big differences in capital and running costs. What also makes a difference is location relative to markets, as figure 9.3.1 shows.

Table 9.3.1 Crop grown in six schemes in Manicaland

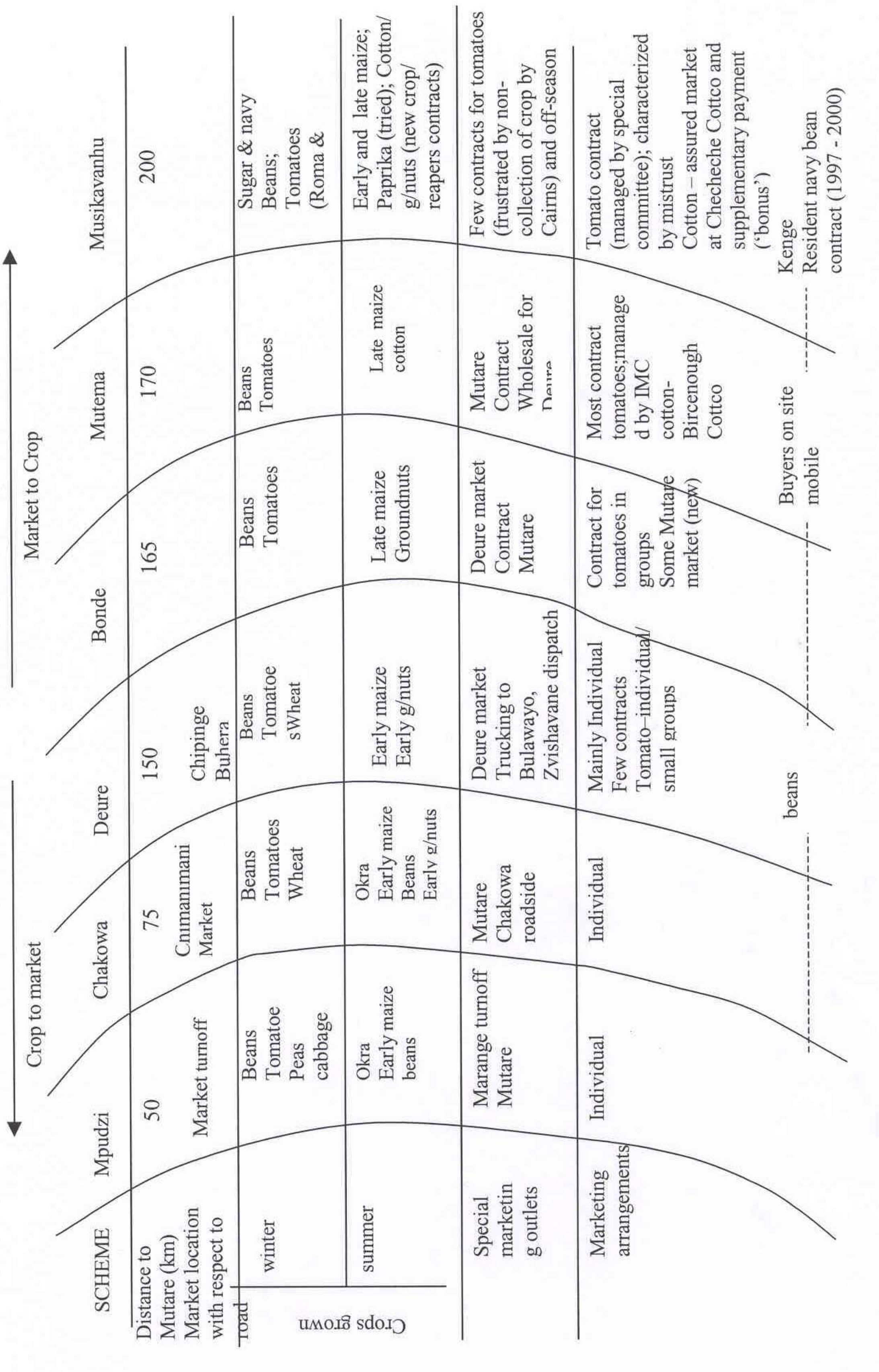
Crop	Scheme Name and percent area planted					
	Old			New		
	Deure	Mutema	Chakowa	Musikavanhu	Mpudzi	Bonde
Summer						
Maize	85	30	74	40	36 &(30*)	85
Groundnut	15	12	15	10	24	15
Cotton		56		40		
Okra	1		6			
Tomatoes			2	10	12	
Beans					24 & (24*)	
Paprika				0.6		
Winter						
Beans	39	4	91	76	24	65
Tomatoes	25	80	4	7	12	31
Wheat	37	15	2	0.1	24	3
Peas					12	
Maize				14	24	
Cabbage					12	
Onion		1	2		2	
Rape/kale				2		1
Source: Field data. * Denotes second crop grown in the same year and same cropping season						

The similarity in crop production at most of the study schemes is influenced by the family livelihood food needs and marketing requirements for the different crops. Overall, summer crops are linked with livelihood needs, and winter crops linked with cash crops. That many programs continue to propose crops outside the reality reflects a communication gap between planners, designers, local extension officers and farmers (Scheer 1996).

Maize and groundnuts

Maize a livelihood crop dominated cropping programs on the six study schemes: everybody *with reliable supply* plants early staple maize. Early planting enables farmers to sell it as green maize in the local "niche" markets boosting cash income in summer as reported earlier by Rukuni (1984). At Mpudzi the early maize crop can be entirely sold off at Marange and in Mutare. The farmers normally plant a second crop that is mainly rain-fed and

Fig 9.3.1 Schematic summary of crops to markets or market to crop in the six study irrigation schemes in Manicaland



this meets their family food requirements[4]. At Musikavanhu some farmers sold as green maize part of the early planted crop and a winter maize crop depending on the capacity of the market. The balance from the two crops forms the family food reserve. Groundnuts form an important rotation with maize and their planting patterns are in harmony (similar to dryland farming). However areas grown to groundnuts are always significantly lower as shown in table 9.3.1. Groundnuts are grown as a livelihood crop but generates substantial cash returns, with "niche" markets as at Deure and Chakowa specifically benefiting the early growers. Mutema, Bonde and tail end blocks at Chakowa had unreliable water deliveries and tended to plant both crops later to increase security with rain water.

Wheat grown at the study schemes is for *sadza* and homemade bread making it a livelihood crop. As detailed in chapter 4, Deure farmers explained that all transactions for wheat do not involve cash. The high fertilizer and labour requirements erode its viability even for schemes with no pumping costs. Where farmers are required to pay energy costs, EWs openly discourage farmers from growing the crop as noticed at Bonde. Some Mutema and Bonde farmers grow wheat because of its tolerance to salinity.

Cotton

Mutema was the only scheme that had a significant proportion of cotton in summer. There are two cotton depots in the vicinity of the study schemes. In spite of good input support and local cotton depots cotton is grown as a “livelihood” crop only at Mutema where there are frequent water delivery problems making maize production risky as well as salinity problems that rule out bean production**.** At Musikavanhu irrigated cotton is minor to the main dryland crop grown outside the scheme area that occupies the greater part of the farmers' time in summer. Some prefer renting out their irrigated fields during summer to civil servants or other farmers while they concentrate on the bigger dryland cotton crop[5].

Beans

Beans are the dominant cash crop grown in winter at all study schemes except Mutema in line with findings by Rukuni as regards Manicaland province (Rukuni, 1984). Farmers particularly like growing beans because they have low input requirements, low water demand, grow in winter when there are no alternative crops, dry weather at harvest favours good quality, are not perishable, selling is an individual cash transaction, are nutritious and retained for home consumption and have competitive returns (Badenhorst and Crosby, 1991). The low water consumption by the bean crop is not always directly translated into system water savings. Farmers in winter tend to get what water they want (based on their perception of crop needs) due to excess supply as detailed in Mpudzi case study in chapter 8.

The majority of schemes grow sugar beans (*Phaseolus vulgaris*) that are bought by various companies based in major towns likes Harare and Mutare. They resell or direct package and wholesale to retailers. Musikavanhu farmers had contracts for growing special canning varieties like navy beans with a company in Mutare. Mpudzi grows *pfumisai* and bata (butter) beans as additional varieties especially as the second bean crop planted in August peculiar to schemes in cooler areas.

Tomatoes: early for table “niche” marketing and later main crop for canning

All the schemes studied grew two crops of tomatoes, like most schemes in the southern part of Manicaland[6]. The first crop coming in summer is subjected to a lot of damage from blight and its survival is dependent on either a relatively dry year or a good fungicide control program. However the crop can offset the investment as it fetches lucrative prices on the table

[4] A significant proportion of the farmers also rent dryland plots to grow additional maize.

[5] Bonde farmers also prefer growing cotton in dryland plots where they have bigger areas.

[6] The schemes in the north namely Nyamaropa and Nyakomba and numerous small “informal furrows” are normally not big tomato growers. Like Mpudzi they go for peas and a second crop of beans because of their cooler climate.

"niche" market. Chakowa, Mpudzi and Deure grow most of their tomatoes entirely for their established table markets.

The second tomato crop is mainly for canning and characterised by group verbal contracting for a scheme, management block, hydraulic or other formal or informal grouping by agents of one main canning company in Mutare. The company provides seed and transport and deducts from group deliveries.

During harvest and collection the farmers use their own institutions to monitor, record individual and bulk deliveries, follow-up and collect bulk payment, deduct individual expenditures and effect individual payments. Musikavanhu farmers have special committees for this activity while others like Mutema and Bonde leave it to IMCs, because virtually every farmer is involved in canning tomato production[7]. Transparency is emphasised and the responsible representatives spend considerable lengths of time explaining the financial transactions to the individual farmers depending on their levels of understanding. Incumbents involved in any misunderstandings are sanctioned by loss of confidence leading to loss of votes. The persons responsible for collection of payments are given transport and subsistence allowances which are consistent with the actual cost of travel and food.

There is a general feeling especially among the buyers that Mutema and lately Bonde are among the best tomato producers in the Save River valley. A number of factors have been advanced among which is the lack of opportunities for side marketing, and use of sprinkler irrigation.

Other fresh vegetables

Chakowa grows okra for a specific niche market but this has tended to fuel inequity between blocks. The lower block cannot grow the okra citing issues of fertility and also lack of water. The fact that some downstream farmers have taken to marketing the okra crop tends to mask the actual effect of this special crop on the water distribution practice. The Mpudzi farmers in the upper block are responding well to the market demands but taking more than their share of water. They have a mixture of both livelihood crops and cash crops like peas and cabbages. It is the only scheme in the study where some farmers consistently produce three crops per year on the same piece of land[8]. The lower blocks with lighter soils is not sharing the prosperity of it upstream neighbour raising issues of soil fertility.

Marketing structures

The study shows that marketing structures are commodity related for the major commercial crops and are “niche” dependent for the minor and livelihood “green crops”. Rukuni (1984) reiterated the importance of these local markets in the area surrounding the schemes. This study has shown that the Musikavanhu scheme is also least preferred by canning tomato contractors due to distance which may be one reason that forces farmers to grow a second maize crop or cotton. The interactions of the Save valley markets is summarised in figure 9.3.1.

9.4 COMPARING MSSS AND THEIR ELEMENTS

Different institutions have supported smallholder schemes over the years, with Agritex extension services being the most common. Their services have varied from agronomic advisory, water delivery support, infrastructure maintenance and administrative support. Table 9.4.1 summarises some of the attributes of the extension service at the six study schemes.

[7] Canning tomato production is more developed in Manicaland smallholder schemes than other provinces.

[8] Smallholder schemes near large markets commonly produce more than two crops a year..

Table 9.4.1. Summary of extension services at study schemes

Description	**Scheme name**					
	Mutema	Deure	Chakowa	Bonde	Musikavanhu	Mpudzi
Study Area (ha)_	180	302	89	260	72	50
No. farmers	200	423[9]	115	260	60	50
Hydraulic blocks	2	7	4	6	6	2
No. EWs	2*	6*	1*	2*	1*	1*
Water controller	1*	1*	Nil	Nil	1**	Nil
No. water bailiffs	3*	5*	2*	8***	6**	Nil
Administration staff No. (shared)	3* (Tawona)	3*	1* Nyanyadzi)	2* (Deure)	0 (Chibuwe)	Nil
Maintenance						
Staff	2*	5*	3*	Nil	Nil	Nil
Equipment	Old, unusable	Basic, hand tools	Basic, hand tools	Set basic sprinkler	Nil	Basic pipes
Fee level ($Zim)	145/ha	145/ha	145/ha	400/ha	1500/yr	Nil
Payment record	Fair	Good	Poor	Poor	Fair	Nil
*Govt employees ** elected farmers*** had payments conflicts						
Source: Field observation and Agritex records						

Extension staff at the study scheme comprise of diploma or degree holders and certificate holders, who are referred to as extension officers and extension workers respectively. An officer usually stationed at the district office serves a number of smaller schemes like Mpudzi. In the late 1990s Agritex made a drive to improve service delivery using the concepts of team approach and specialisation. The strategy was adopted at some schemes and later reversed as detailed for Deure in chapter 4. Extension officers' stationed at irrigation schemes execute standardized master farmer training programs in crop and livestock husbandry and finance. They also support farmers in water management. Field days and competitions are rarely held at schemes with inadequate and unreliable water delivery. During the study period I did not witness or get records of field days at Chakowa, Mutema and Bonde. Generally there is very little written material and no specific literature on irrigation exists at schemes. Attempts to prepare an extension worker manual on irrigation have never taken off. The training and support services at Deure and Tawona in Manicaland were rated poor and average respectively against other schemes in Southern Africa by a study promoting agro-business in smallholder irrigation schemes (Chancellor and Hasnip 2001, pp8).

Water delivery operational support

At Deure, the extension supervisor plays a strong and major role in monitoring, sanctioning and control of water through the water bailiff and water controller, very similar to old irrigation manager. This level of authority was not evident at Mutema and Chakowa. Extension agents are not involved in daily water management issues in the new schemes Bonde, Musikavanhu and Mpudzi.

Generally the water bailiff task is prioritised over the maintenance duties. Whenever a water bailiff vacancy occurs a replacement is drawn from the maintenance gang. Water bailiff training generally involves a 3 months attachment to a practicing water bailiff except at Musikavanhu where the elected group leaders perform the water allocation tasks. At Deure each water bailiff works within a specified block and is responsible to the block extension worker. At Mutema the water bailiffs are answerable to the water controller. At Chakowa water bailiffs report to the extension worker who jointly with the IMC protect them from "harm" by the people that may have been offended by any of their work related actions. At

[9] These were the latest figures from Chancellor and Hasnip 2001 draft, pp8.

Mutema no water allocation sanctions are imposed relating to maintenance payment. The main committee at Musikavanhu imposes water allocation sanctions to defaulters in electricity payments. No such sanctions have been imposed on maintenance fee payment perhaps because the scheme is still fairly new. At Mpudzi during the study period there were no operational fees paid and there was no maintenance account held.

At Deure and Chakowa water bailiffs work everyday of the week including public holidays but organise among themselves for days off duty. The water controller at Deure and Mutema also covers for any water bailiff in emergency. Elected group leaders who are not paid allocate water to fellow group members at Musikavanhu. At Musikavanhu the name water bailiff is used to refer to the block elected member who controls the "hired" pump operators and co-ordinates the work of the group leaders.

The duties of the water controller at Deure, senior water bailiff at Mutema and water bailiff at Musikavanhu are virtually the same although their modes of appointment, motivation and remuneration are different. They both provide the practical means of exercising the across-block flexibility that is required to manage scarcity due to canal delivery capacity limitations in Deure and imposed scarcity due to power management or pump breakdowns at Musikavanhu. The “management” of smaller schemes like Chakowa did not include water controllers in its design and institutional requirements, and this may have allowed the acute across-block distribution problems. Studies of water distribution at Nyanyadzi pointed out this weakness - and could have contributed significantly to the conceptualisation of the Musikavanhu scheme design (Tiffen and Harland 1990).

Administrative support

There is very little direct administrative staff for the new schemes unlike the old schemes as shown in table 9.4.1. Musikavanhu has housing for extension agents and a combined office block with Chibuwe, but no separate and specific clerical service even after the training program. There is no specific clerical service at Bonde and Musikavanhu to carry out specific functions like filing water and energy bills or following up issues. Either farmers or extension agents do the follow up issues but no filing exists. Mpudzi has no clerical staff and the farmers have no interest in it as they do not have operating costs to worry about.

Farmers’ hold meetings under a *mucha* tree at Deure and Mutema. There is also an "outdoor" meeting place in the Bonde river basin for Bonde. Chakowa at least has a shed with benches, although its roof has been blown away several times. At Musikavanhu farmers sit on the floor of the shed because there are only two chairs and a desk for each hydraulic block. There is effectively no provision for the farmers to have access to their own filing, hold meetings in offices or communicate directly by way of telephone or other media. Therefore meetings attended by farmers and other community leaders or with traders are not recorded and filed at these premises. It is understood that the secretary takes minutes. Government administrative staff do not cater for farmers' institutions direct needs.

There is a need to train and support farmers in administration, legal and financial management. This is particularly important for technologies that are not so simple as to be classified as traditional[10]. It needs to be addressed whether to adopt a joint upgrading exercise for farmers and extension agents together or to adopt separate programmes. The SISP approach is focused at direct farmer training.

Clearly considerable confusion and weaknesses exist in approaches to terotechnology for irrigation. Older schemes are left with variable staffing and resources, and new rhetoric on farmer-management has so far not embedded effective longer-term strategies for groups to plan for maintenance needs. The Negomo model - where a donor has supported evolution of a maintenance unit to serve the scheme area with services paid for by local IMCs - is not yet

[10] Cornish describes as traditional labour-intensive, non modern systems which do not need money and skill (Cornish 1998, pp19 citing Keller 1990).

functioning, due to conflicting expectations between farmers, donor and state and agency officials (see Makotore 2002).

Administrative structures of Irrigation Management Committees (IMC)

Some attributes of the irrigation management committees of the study schemes are summarised in table 9.4.2. All the schemes have basically a minimum of two layers of committees that is block committees representing hydraulic units and a main committee. The main committee is constituted as a "federation "of the block committees. Farmers in a hydraulic unit elect block committee members. As discussed in chapter 2 Agritex is instrumental in the formation of committees and expects to work closely with them. Each committee is expected to have a constitution and bye –laws. although it was not easy to access the constitutions of the schemes except Mutema.

The IMC constitutions normally require that election of office bearers be done within specific time frames. However at Deure and Chakowa there were committees that had already served for longer periods when the study started in 1998. At Mpudzi the committees had not changed since the schemes started operating. Chakowa and Mpudzi later had elections during the study period. At Mutema there have been frequent elections and there is a clear record of main office bearers.

Table 9.4.2 Attributes of Irrigation Management Committees at study schemes

Description	**Scheme Name**					
	Mutema	Deure	Chakowa	Bonde	Musikavanhu	Mpudzi
Hydraulic/ Federal area (ha)	180	300	89	260	70	25
Block committees	2	6	4	6 **	6 (groups)	2 (separate)
Functional committees	Nil	Nil	Nil	1	4	1
Terms of office	2*	Undefined	Undefined	1 (started as 2 then reduce)	1*	Undefined
Bank accounts No.	1	Unconfirmed	Unconfirmed	1	1	Unconfirmed
Priority function-1	Tomato Marketing	Distr. canal maintenance	Weir intake cleaning	Block Electricity payments	Electricity payments	Intake cleaning
Function-2	Electricity payment	Water mgt, supply	Conflict Mgt.	River intake cleaning	Water & electricity mgt.	Sourcing repair funds
function-3	Water Mgmt	Conflict resolution	Beans Marketing	Tomato Marketing	Beans & tomato marketing	
Function-4				Block pump repairs	Block pump repairs	
Source: Field observation Agritex records, *can have more ** based on booster pump stations						

The situation is different at the new Bonde and Musikavanhu schemes where elections have been held annually. Office bearers have no limits to the number of terms. What is emerging at Musikavanhu is similar to practice at Mutema where some office bearers are recurring even though they may be voted out for a year or two. In 1999-2000 a full compliment of office holders in Musikavanhu Block A1 was made up of 42 percent of the farmers, because of numbers of positions – an issue of concern to some. The need for farmers' involvement in administration and finance as prescribed for IMT has tended to increase the number of committees (FAO No.58). The FMIS have no formal employees except the Musikavanhu pump operators, whose employment conditions leave a lot to be desired. Records and minutes and any "official correspondence" by the committees are prepared and kept by the respective elected secretaries at their homes and transferred to the next elected office bearer. This lack of proper data and information storage and retrieval structures and procedures leads to loss of institutional memory.

As table 9.4.2 shows most of the IMCs are multifunctional. The advantage being efficiency in that they can serve the different needs of the farmers and get a fair amount of work within their term of office. This was particularly noted at Mutema, Bonde and Musikavanhu where the IMC plays a significant role in tomato marketing. This frees the non-office bearers who can then concentrate on farming. In some cases the effectiveness of IMCs and priority to water delivery functions has been compromised by the multifunctional roles for example the Mutema IMC seems to prioritise tomato marketing functions. In all cases except Mutema, ensuring water availability in the system has emerged as the priority function, with coordination and enforcement of electricity payment as a key priority for pumped systems. In Deure (block D2), Bonde and Mutema, the IMCs have been active in searching for surface water options to replace the need for pumps.

Local Government

Local councillors and traditional leadership are actually under the same Ministry and are loosely regarded as local government[11]. Table 9.5.3 summaries the roles played by local government in the six study schemes. The responsibility and allegiance of councillors to people at times puts them into conflicting situations and views with other government functionaries as happened at Bonde and Musikavanhu.

The Buhera district council made a decision to source funds for weir and canal construction for Bonde irrigation scheme when Agritex and DWD forged ahead with development of an electric pumped scheme. In the development of Musikavanhu local government refused to prioritise tarring of the road to Musikavanhu citing high future maintenance requirements. They instead advocated for a loop road connecting Block B to the main road that Agritex turned down as not directly related to the project.

All districts universally vet prospective plotholders to ensure that they come and are registered within the respective district. They all use the individual's identity number. This exercise is interesting around Deure where four districts converge within a short distance.

Local government is not directly involved in water allocation and maintenance of the six schemes. Local government plays a role in conflict resolution in situations where the local Chief and councillor are inadequate. The Buhera district administrator had to go to Bonde to negotiate for development to progress. Irrigators wanted further development work to stop until they were guaranteed a reliable water delivery as detailed in chapter 7.

New roles of DWR and ZINWA

The DWR is responsible for the operation and maintenance of the Mutema and Bonde water delivery system. In both cases the funds allocated were only enough to cover staff salaries and a few basic running costs, being less than 20 percent of requests as detailed in chapters 5 and 7. There was no provision for maintenance. The schemes tended to rely on Agritex allocations meant for distribution and application subsystem development. Inadequate

[11] In this study local government denotes all institutions like district administrator's office, council and councillors under the Ministry of Local Government except traditional leadership. The traditional leadership was studied separately due to its greater visibility in practice at some schemes.

maintenance resulted in poor water deliveries that in turn affected cropping programs in both cases.

The government of Zimbabwe carried out an extensive review of the water sector in the period 1994 to 2001 with bilateral donor assistance. The review focussed on water allocation principles, water charges and roles of the government and other institutions in water affairs. Three important outputs were finally produced that is:

⇒ A revised water act was promulgated which replaced the perpetual priority date system of water rights allocation with time-based water permits that are subject to periodic review.

⇒ A clear water policy and strategy document was compiled that clearly gave rise to the separation of policy and control aspects from the operational roles. Policy and control aspects were retained in a streamlined Department of Water Resources[12].

⇒ A new parastatal called ZINWA was created by an act of parliament. Its main role was to take charge of all the operational responsibilities of the former Department of Water Development. The new institution was given the mandate to provide water related service to both government and private sector at competitive prices.

ZINWA is responsible for planning, designing, implementation and day-to-day management of all water retention structures. They provide a secretariat to the catchment councils that are now charged with water allocation decisions. Catchment Managers and Data Managers undertake executive functions in water service delivery and water allocation respectively in their areas[13]. Details of the new water act in Zimbabwe and the ZINWA act are available on the internet.

9.5 EVERYDAY PRACTICES OF O&M VERSUS ORIGINAL PLANS

There is no standard or guideline for the allocation of staff to water allocation and maintenance activities. Smallholder irrigation schemes maintenance has never been formally planned since independence, and no guidelines exist as to the recommended institutional structures. Each scheme tends to have its own arrangements. In government-run surface schemes a foreman is usually in charge of the unit as observed at Deure and Chakowa. The foreman is usually a builder or a handy man. The main requirement is an ability to plan daily work activities, allocate tasks, control and be accountable for equipment. Tasks done by teams vary with schemes but generally they prioritise water delivery facilities like canal cleaning and repair. In the new schemes as shown in table 9.4.1 there are no individuals assigned to terotechnology. The farmers claim that they do most of the work themselves. It can therefore be crudely summarised that the concept of farmer management in the new schemes is doing away with formalised terotechnology or handing over equipment care and maintenance responsibility to farmers. Therefore in spite of adopting sophisticated technology and aiming at high water efficiency the sustainability aspect is left by the wayside.

An inventory done on the six schemes showed that the old schemes had old and obsolete tools, equipment and vehicles as shown in table 9.4.1. The same table shows that there is virtually no maintenance equipment at the new schemes other than tools for the repair of sprinklers at Bonde and Mpudzi and PVC at Mpudzi. This assumes that farmers will be required to organise and source the equipment without guidelines or they hire or use personal artefacts as observed with Deure main canal cleaning in chapter 4. The major problem with all these approaches is that the new systems, especially those with pumps, are all more

[12] With this rationalisation it is proposed that the policy and control arm in the ministry be renamed department of water resources to depict the consolidation of the development activities in ZINWA.

[13] Catchment Managers are overall responsible for all catchments water services. Data Managers are responsible for hydrological data acquisition, processing and dissemination.

sophisticated and require specialised repair and maintenance equipment as highlighted in chapters 5, 6 and 7 with reference to the Mutema, Musikavanhu and Bonde. There is no equipment to check for proper functioning of sprinkler systems at Mpudzi.

Water Delivery Functions of IMCs

The objective of Agritex irrigation scheme planners in encouraging the formation of IMCs is to involve farmers in the management of the water delivery system (Bonde FR 1992, Mpudzi FR 1993, Musikavanhu FR 1992, Makadho 1990). Some persons have stated that the only successful contribution of IMCs is in conflict resolution and acting as go-betweens between Agritex and farmers (Pazvakavambwa 1995). This study found that the IMCs play an active role in the water mobilisation and across-block and in-block water allocation and distribution. Table 9.5.1. summarises the relative contribution of the different actors in the water delivery operation.

Table 9.5.1 Relative Roles of Main or Block IMCs (MI/BI), Agritex (A), DWR (D) and Farmers (F) in water delivery operation in the study schemes

Description	**Scheme Name**					
	Old			**New**		
	Mutema	Deure	Chakowa	Bonde	Musikavanhu	Mpudzi
Flow Diversion /Abstraction						
Decisions	A	A	A&I	MI	MI	F
Operation	D	A	A	D	F	F
Monitoring	(D)	(D)	(D)	(D)	{D}	(D)
Across block Water Distribution and Allocation						
Decision	A&F	A&I	(F)	{(I)} [(F)]	(MI)	{(I)}
Actual Operation	A	A	A [(F)]	{(I)}[F]	{(MI&BI)}[F]	{(I)}
Conflicts Resolved	A&MI	A&MI	(A&I)	A&I	{MI}	I
Monitoring	A	[A&MI]	(A)	{A}	(A&MI)[F]	[{MI}]
In block Water Distribution and Allocation						
Decisions	A	A	A	(F)	(BI&F)	(F)
Water Bailiff instructions	A	A	(A)[F]	{F}	(BI) [F]	{F}
Conflicts resolved	A	A	(A&I)	{(F)}	(BI)	{(F)}
Monitoring	A	A	(A&BI)	{BI}	{MI&BI}	{BI}
Individual Plot Water Application						
Decision	A	A&BI&F	A&BI&F	(A)[F]	BI&F	(A)[F]
Instructions	A	A&F	(A)[F]	BI&F	MI&BI&F	F
Monitoring	(A)	A	(A&BI)[F]	(A)[F]	{MI}BI[F]	(A){BI}[F]
( ) weak, not well done/clearly defined, {} not anticipated, [ ] actual practice or by default						
Source: Field Observation						

The water allocation decision processes, actual operation leading to a delivery, conflict resolution and monitoring are influenced by both the phase of the delivery system as well as the system configuration. Different system design configurations influence the performance of the irrigation system. The relative roles in table 9.5.1 are therefore a culmination of the interactions of design, operation, maintenance and the other institutions involved in the management of the scheme.

Table 9.5.1 shows a clear shift from Agritex taking a lead in the older schemes like Mutema, Deure and Chakowa to a weaker, less defined role and sharing with IMCs and farmers in the new schemes Bonde, Musikavanhu and Mpudzi. Water mobilisation - that is diversion and abstraction decisions and operation - have seen the most definite shift from government to IMCs and farmers. There is a weak monitoring by the DWR. Inter-block operations account for the high level of equity observed at Deure and Mutema, not found at Chakowa. In both high equity schemes, flexible design allows water to be moved completely from some hydraulic units to others by use of movable gates and valves. This limitation is noted at Chakowa and the farmers are acutely aware of it resulting in completely different cropping programs and livelihood strategies as highlighted in chapter 3. The earlier approach of a strong government institutional structure enforcing equity would now be in antagonism with the farmer empowerment process. The only institutional alternative now would be to provide a strong legal framework for equity enforcement to the current IMC and local government structures.

The new schemes were planned and designed to achieve equity through technological intervention. There was a general lack of anticipation of management-related equity issues at planning and design stage. This has resulted in weak structures and farmers operating division structures in ways they perceive are appropriate to lower costs or give them more water. In Musikavanhu head end farmers first lower the main flow gates and get more water and therefore complete irrigation earlier than the downstream farmers as discussed in chapter 6. They then close off gates on the proportional dividers hoping "now to lower costs" but instead send the water to the unsuspecting downstream farmers with a fixed number of siphons. Water spills over canal embankments at checks enhancing maintenance requirements that are themselves not even well planned. Bonde farmers who have sufficient head to turn sprinklers take a free ride of the water in the NSD and manage to crop successfully even in saline plots and to lower their block electricity bills as discussed in chapter 7. The Mpudzi upper and lower blocks have used the alternative day abstraction principle during scarcity.

In-block operations are generally well defined and only in extremely low equity schemes do farmers take water without authority from the block committees. The Chakowa okra farmers steal water to irrigate the crop after harvest-and-fertilisation. Some Musikavanhu farmers may forego their irrigation turns due to individual cropping programs. This has the effect of complicating the rotations, and the match of them to the proportional division structures operating outside the design, to set operational combinations and permutations of gates, and to groups and individual irrigators. However the common electricity bill that is divided equally by all farmers has nullified the expected high efficiency from the tight water control. Farmers apply water as long as the pumps are running because they will be billed anyway. They see no reason to worry about individual crop scheduling or even skipping an application as there is no facility to earmark the saving and adjust the bill to reflect the actual water or energy consumed per farmer[14]. During scarcity Mpudzi farmers split the block into upstream and downstream hydraulic units that irrigate on alternative days using the same principle as Chakowa block A.

The water application processes are only simple for the Mutema scheme where almost all responsibility rests with Agritex. While IMCs and farmers decide and irrigate when they want at Deure, Agritex retains clear authority through the water bailiff and supervisor as seen in chapter 4. The Chakowa situation deteriorates to free-riding by head-enders and conflict with ad-hoc organised downstream groups temporarily appropriating water at night to save crops. The rest of the farmers plant late in summer and in winter when the competition for water is reduced (head-enders have finished planting) as discussed in chapter 3. The new

[14] The SISP coordinator also corroborated this fundamental weakness in pumping schemes where farmers pay jointly for electricity. The program started seriously considering having on-demand reservoirs individual metering and crop based scheduling on a farmer basis (Personal communication Hans Moorlag 24/10/2001).

schemes have a greater contribution from IMCs and farmers in the application operations. There is however lack of anticipation of the need for IMC contribution to monitoring in Musikavanhu to avoid head-end tail-end situations described earlier. In Mpudzi individual farmers apply water to all crops including night irrigation in clusters and take periodic dry days when they simply do not irrigate. There is neither IMC nor government monitoring and weak Agritex contributions in scheduling, leading to continuous operation of sprinklers when farmers irrigate based on their perceptions of crop water needs. The result is unnecessary wear costs, nutrient leaching and waterlogging as discussed in chapter 8.

In pumped schemes minimising cost of electricity is playing a significant role in controlling the amount of water use as seen with “target bill setting” in Musikavanhu as discussed in chapter 6. Planners did not anticipate this use of energy costs as evidenced by the optimum `water application using Penman crop water requirement’ approaches only. There is no analysis based on optimum return on investment in the Agritex feasibility studies or the monitoring reports that have been produced to date.

Infrastructure Maintenance Roles of IMCs

Table 9.5.2 depicts the responsibility for decision-making, execution, and financing of maintenance. It depicts a pattern very similar to that of operations as shown in table 9.5.1.

Table 9.5.2 Relative Roles of Main or Block IMCs (MI/BI), Agritex (A), DWR (D) and Farmers (F) in water delivery infrastructure maintenance

Description	**Scheme Name**					
	Mutema	Deure	Chakowa	Bonde	Musikavanhu	Mpudzi
Diversion /Abstraction Maintenance (weir/pump unit/ supply canal/pipeline)						
Decisions	A&D	A&MI	A&MI	D	A&MI	BI
Execution	A&D	A&MI	A&MI[BI]	D&I	MI	BI
Ownership	(D)	A&D	A	(D)	(MI)	(A/I)
Financing	(A&D)	(A)	(A&I)	(A&D)	MI(Donor)	[A&Donor]
Across block Maintenance (distribution canals/pipelines/NSD/gates/valves/measuring structures)						
Decisions	A	A&I	A	(MI/D)	{MI/BI}	BI
Execution	(A)	A&I	A	(D&MI)	(MI/BI)	BI
Ownership	A	A	A	{(MI/D)}	{(MI/BI)}	{(BI)}
Financing	(A)	(A)	A	D	(MI/BI)	{BI}
In block Maintenance (tertiary canals/pipelines/field laterals/hydrants/gates)						
Decisions	A	A&(F)	A&(F)	(BI)	BI	BI
Execution	A	A&F	(A&F)	(BI)	(BI&F)	BI
Ownership	A	A	A	{(BI)}	{(BI)}	{(BI)}
Financing	(A)	A&F	(A&F)	(F)	{(BI&F)}	{(BI)}
Application Maintenance (hoses/laterals/hydrants/sprinklers/siphons)						
Decisions	A	F	F	F{BI}	(F){BI}	(F){BI}
Execution	(A)	F	F	F	F	(F)[Donor]
Ownership	(A)	F	F	F	(F)	F
Financing	(A)	F	F	(F)	F	(F)[Donor]
( ) weak, not done well/clearly defined, {} not anticipated, [ ] actual practice or by default						
Source: Field Observation						

There is more clarity in the old schemes, in both the water mobilisation (diversion or abstraction) and in the application subsystems. The area with most confusion and weak structures is the across- and within-block maintenance in new schemes where responsibilities are with the IMCs. The cultural weaknesses in co-operation and maintenance identified by

Makadho (1984 in Blackie *opcit*) suggest that new schemes whose subsystem designs have high requirements of these two attributes have a high probability of being weak.

The case studies reveal fundamental under-financing of water mobilisation maintenance in all schemes. This has negative effects on water deliveries of pumped schemes. Gravity schemes' responses depends on the institutional strength. In Deure the farmers “appropriate” the water mobilisation in order to sustain themselves thus leveraging the simple WDSS. At Chakowa the head-enders have a flourishing “market gardening in okra” while the tail-enders have to turn to supplementary irrigation. This had a damaging effect on maintenance available to rectify the damage due to cyclone Eline as there was no unity of purpose. The Mpudzi scheme makes no financial provisions for maintenance and was bailed out by Agritex and the “donor” when the cyclone struck.

Responsibility for inter- or across-block maintenance has been importantly shifted from government to IMCs. However the ownership is not clearly defined, resulting in lack of financing. The decision and execution of maintenance for this infrastructure are weak at Musikavanhu and Bonde. The semi-demand subsystem design at Mpudzi that uses buried pipes to individual plots reduces the maintenance requirements at the distribution level. However the important question of clear ownership structures for sustainability persists. Chancellor and Hasnip also identified unclear identity and ownership of the scheme as a problematic for setting objectives and this makes it difficult to engage irrigators as full partners in strategic planning (Chancellor and Hasnip 2001, pp17).

Farmers at Deure and Chakowa take up maintenance of intra-block infrastructure. At Mutema the farmers insist that government should continue being responsible even though there is a clear under-financing. Here pumps stay working partly due to the farmers’ attitude and also concerns of the Ministry historically responsible for the technology. The new designs for Bonde, Musikavanhu and Mpudzi differed from the Mutema in a variety of ways in community responsibility. Musikavanhu boreholes are not looped that is the discharges cannot be shared across blocks and they were handed over to farmers right from the onset. The farmers are scared of maintaining the boreholes in particular and have even initiated negotiations with DWR on their own as discussed in chapter 6. The Bonde main river pump repair is a problem even for DWR, and it is not reasonable to consider farmer maintenance. The field pumps are smaller standard modules on the market and similar to smallholder schemes developed in the same era in other parts of the country. However at Musikavanhu and Bonde in chapter 6 and 7 it is shown that farmers give priority to paying energy costs. At Mpudzi - where there are no energy costs and very little maintenance requirements for the distribution subsystem - one might expect a lot of attention in maintaining the sophisticated application system. In fact there is unrealistically low maintenance - a situation also occurring at Bonde due to breakdowns and power cuts.

The monitoring and enforcing maintenance or repairs to equipment like pressure regulators, hoses and sprinklers in gravity systems presents problems because: (1) while maintenance is actually a cost to farmer (2) the effects of not maintaining are not felt directly by the individual farmer. The effects on the hydraulic performance of the system are beyond the comprehension of the farmer and the local Agritex staff. There are no facilities for determining the level of equipment wear. There are no guidelines to show farmers the limiting levels of leakage or the sprinkler nozzle size, at which the system performance becomes adverse to the individual application or group water distribution. This results in failure to apply water uniformly which is the objective of sprinkler irrigation (SAZS 363:1996 pp34)

Traditional Leadership

Traditional leadership has played roles in the identification, development and management to different degrees in the six schemes studied, as summarised in table 9.5.3. They include brokerage and leverage, but often in practical situations, where action with local people is involved in sitting with and selection of plotholders. Agritex was central to virtually all the activities and therefore is not mentioned in the table.

At Bonde, the local leadership might not have spearheaded technological change but they were closely following events. The local Chief reminded Agritex that the issue of river pumps operation, repair and maintenance responsibility and financing was never specifically mentioned during planning and design stages. The same Chief was consulted in planning the in-field canal lining of Deure in 1991[15].

The Deure and Bonde traditional leadership was involved during schemes implementation. Initially at Deure development they were party to supplying *chibaro* labour. The leadership is currently consulted and kept informed during maintenance events. At Bonde the traditional leadership was expected to organise a ritual ceremony for appeasing and informing the land and water owners of the areas about the launch of the scheme. The Chief was also involved in resolution of labour disputes as outlined in chapter 7. Traditional leaders are the final authority for plot allocation in Deure, Bonde and Mutema. At Deure the Chief made final allocations using the list drawn up by combining the council and IMC lists. The involvement of traditional leaders at Musikavanhu and Mpudzi was not clear.

Table 9.5.3 Roles of Traditional Leadership (TL), and Ministry of Local Government (MLG) and Department of Water (DWD) in development and management of the study schemes

Description	Scheme Name					
	Old			**New**		
	Mutema	Deure	Chakowa	Bonde	Musikavanhu	Mpudzi
Identification	DWD (sprinkler)	TL (Initiated)	No role	Not clear	Involved	Not involved
Mobilisation(Planning & design)	DWD	DWD	Not clear	DWD	DWD**	Not clear*
Distribution(PD)	Not clear	TL (consulted)	Not clear*	TL, MLG (meetings)	TL, MLG	Not clear*
Implementation	DWD	TL ,WD	TL	TL, MLG, DWD	TL, MLG, DWD	Not clear*
Plot allocation	TL,MLG	TL,MLG	MLG	TL,MLG	MLG,TL	MLG
Water allocation	Not involved	DWD, TL (at peak)	TL(as IMC)	DWD(Ruti dam only)	Not involved	Not involved
Maintenance	DWD	TL (consulta-tions)	TL,MLG (weir)	DWD(river) TL, MLG (sourcing Funds)	Not involved	Not involved
Scheme level Conflict	TL,MLG	TL,MLG	TL,MLG	TL,MLG	Not clear	Not clear
Disciplinary function	TL,MLG	TL,MLG	Not clear	TL,MLG	Not clear	Not clear
Portfolio in IMCs	TL, MLG	TL,MLG (Referral)	TL(Ex-0fficio)	TL,MLG (Referral)	Not involved	Not involved
Source: field observations, *Agritex or other predecessor agents** as borehole contractor						

[15] "Coincidentally" the first block to be lined was block C where members of the chieftainship are concentrated.

A sensitive related issue is plot renting. This is practiced in all the study schemes, although older schemes have by-laws that forbid plot renting: here the traditional leaderships at least tries to make sure plots stay productive. Musikavanhu and Mpudzi do not have such by-laws. At Musikavanhu, the IMC actually requires that the one renting "*roja*" be formally introduced to the IMC - so that they first clear the outstanding electricity costs and then take over direct electricity contributions[16].

Water allocation activities lie with farmers and IMCs in all new schemes. At Mutema the traditional leadership is not involved officially. At Chakowa the traditional leadership is involved as member of the IMC only. At Deure the Chief is informed and gives his blessing to the inter-block distribution program that is adopted at the summer peak. The situation is similar for maintenance activities. At Chakowa the traditional leadership ended up divided over the weir repairs, leaving a political situation requiring involvement of MPs.

At Deure and Bonde the Chief also plays a disciplinary role. The IMC refers cases to the Chief who adjudicates and if necessary imposes a suitable fine. The plaintiff is then referred back to the IMC to comply with the requirements of the bylaws and pay a fine or get a penalty as appropriate. This means that the Chief here actually works with farmers, Agritex and local government. This kind of authority and uniformity of purpose is not visible at Chakowa. The Mutema situation is fluid, as also reported by Vijfhuizen (1998).

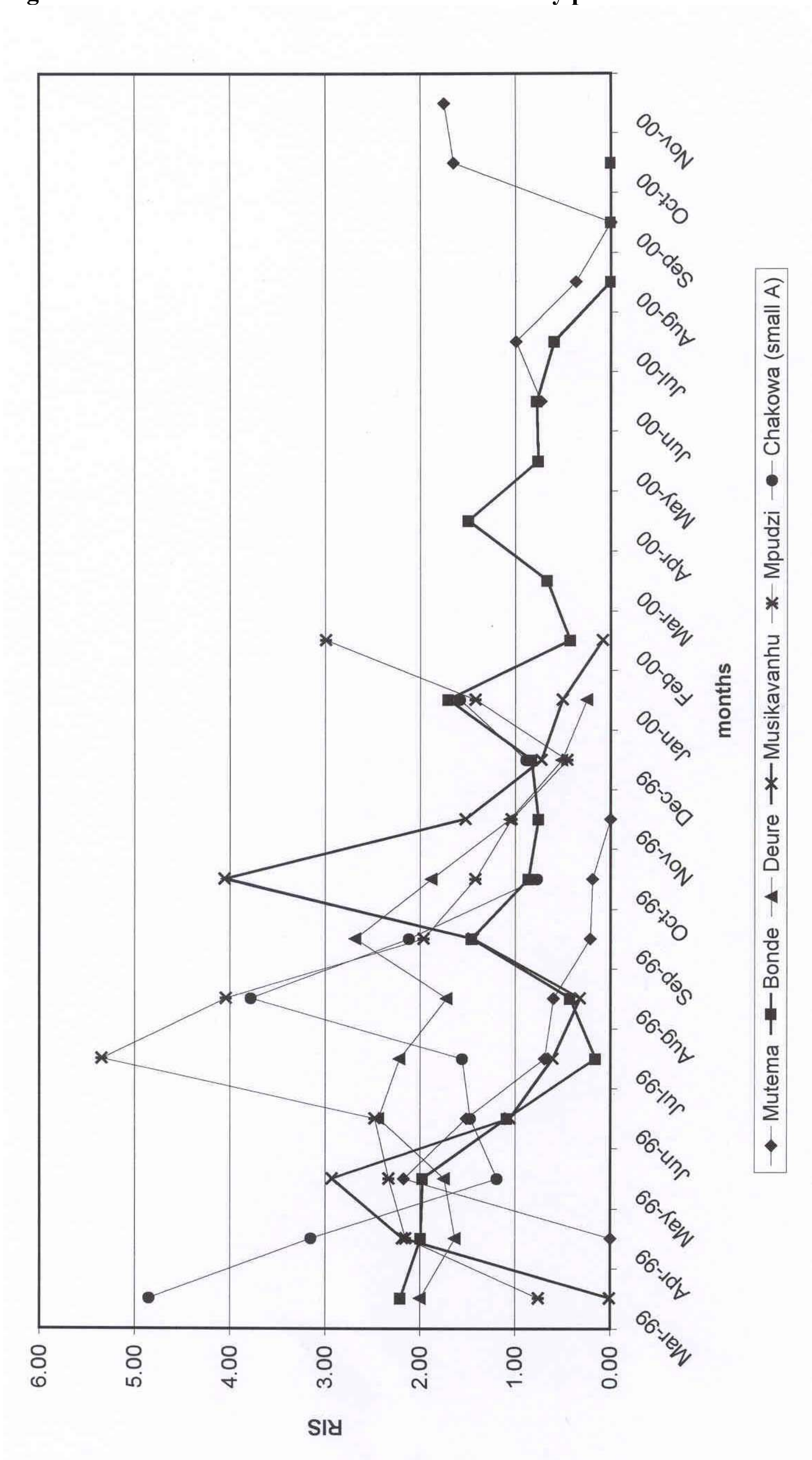
In summary the traditional leadership at Deure is clearly involved in the running of the scheme and in a lot of social issues is regarded as a referral centre. The same leadership is also seen to be playing an active part in the development of Bonde irrigation scheme. However the leadership while it is co-operating with Agritex and DWD in the pumped scheme development clearly and openly expresses its support for the weir and canal option. The Mutema traditional leadership is only involved in social issues namely plot allocation, conflict resolution, providing guidance in dealing with sacred trees and burial sites and negotiating for O&M resources with government institutions. The Musikavanhu leadership was involved in mobilisation guiding developers during land clearing and levelling as regards traditional requirements of interacting with sacred trees and burial sites. They then tended to take a back seat and the IMC is clearly in charge. The Mpudzi traditional leadership has largely remained obscure. It is not clear whether the size of the scheme, the design, and the rather trouble-free operation have a significant exclusion role. The Chakowa situation presents the most complicated relationship that has seen the traditional leadership split along the same lines as the hydraulic units.

9.6 WATER DELIVERY PERFORMANCE IN PRACTICE

Figure 9.6.1 shows the relative irrigation supply RIS for the six schemes[17]. There is no definite pattern related to system distribution and application method. However, there is also no evidence that newer schemes with more sophisticated technologies are using less water, either through better technical control or through scientific scheduling. Rather, it shows that pumped schemes Mutema and Bonde had periods of nil or very low delivery due to pump breakdowns and power cuts during the research period as elaborated in chapter 5 and 6. Gravity schemes tend to maintain consistent high deliveries in winter months from April to September as shown in Chakowa, Mpudzi and Deure. However, Musikavanhu reduced RIS during this time through enforced savings to reduce power costs. The high deliveries due to

[16] The practice of plot renting is increasingly being reported in the new schemes with electricity payments. It is reported to be on the increase at Negomo (Makotore 2002).
[17] Chakowa small block A was used as bench mark for the scheme as it does not have the large excess of head-end Block A and the significant deficit of the tail end blocks.

Fig 9.6.1 RIS of the six schemes over the study period



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"perceived" or real special crop requirements - like peas at Mpudzi and okra at Chakowa - are evidenced by high RIS in July and August. Peak demands in December –mainly due to maize - show as a universal RIS slightly below 1 for virtually all schemes.

Water delivery performance studies generally showed that the RIS for all the schemes is higher in winter than summer. This confirmed a similar finding on surface schemes only by Makadho (1994). Makadho identified waste of water by farmers as largely responsible for the winter excess and the summer stress in some schemes. Smallholder schemes are largely designed to provide water in the hot summer months from October to December before the onset of the rains. The system capacity is set to meet the peak demand for maize as the main livelihood crop. In order to take advantage of the green maize market opportunities, most of the maize crop is planted early and this raises and advances the peak demand. This practice coupled with "monoculture", in schemes like Deure produces a sharp peak that calls for changes from normal rotation supply to "pulsed supply" where all farmers only get a short stream of water more often. This is reflected in low RIS during this time for most schemes. Where the organisation is weak and the scheme design is not flexible enough to cater for increasing canal discharges at peak then downstream farmers get no water. At Chakowa these tail end farmers have re-designed their cropping to fit in with the arrival of the rains in order to reduce risk of water delivery failure imposed by mismatch of the current MSSS to the WDSS.

The winter cropping is generally more staggered in most schemes with at least two dominant crops being grown. The water demand for winter crops is generally much less than that of summer crops due to the lower water requirements of the main crop beans. The other major crops tomatoes and wheat demand less water compared to maize. Therefore in general the RIS for winter is higher than unity in most schemes. The system operation does not take full account of the reduced demand. The mainly run-of-the-river systems imply that any attempt to save water does not have a positive contribution to the catchment water reserves or delivery security. The net result is that water mobilisation practices and duties do not change to match the lower demand except at schemes like Musikavanhu where farmers pay energy costs directly. In winter generally farmers however reduce the irrigation frequency and number of irrigation events applied to a crop. The excess water mobilised is either passed back into the river system from the canals or through drains. Where it goes into drains waterlogging and salinity obtain as witnessed in Deure, Mpudzi, Musikavanhu and Chakowa head-end blocks. Generally farmers are not interested in caring for drains irrespective of the cause and effects of drain maintenance needs.

Systems at Mutema, Deure, Musikavanhu and Chakowa have rotational delivery supply to individual plots and this precluded plot level scheduling. There were no facilities to support scheme level scheduling and therefore rotations or cycles were determined from "experience" during off-peak periods. At peak times the system ability to deliver, as conditioned by organisation and system design flexibility, determined the period between irrigation events. At Mpudzi and Bonde a continuous flow delivery theoretically allowed for limited farmer-based scheduling during off peak periods[18]. However there is no scientific basis for any scheduling. Each farmer irrigates at his/her discretion. Some farmers use interval guidelines supplied by irrigation branch trainers at scheme commissioning. In lift schemes the pump operation schedules irrigation cycles as farmers will irrigate as long as the water is flowing.

[18] Farmer based scheduling during peak periods is not possible because the system capacity is based on the same peak rotation demand applicable to rotational supply systems. The element of flexibility or farmer convenience that converts rigid deliveries to flexible supply is not built in because of economics that guides government investments. Thus the system offers limited rate demand supply during off peak periods. For convenience farmers either do not use sprinklers, or adopt bigger ones, or irrigate in clusters (cycles) as shown in Mpudzi.

This is also an equity issue as energy costs are shared equally irrespective of use in the absence of individualised flow measurement and timing of use[19].

The only scheme that theoretically could practice limited rate individual demand management is Mpudzi. The reliable water delivery and gravity piped water control facilities permit such use. However there are no incentives for such practices. There is no stabilisation of river flow and the farmers' view the delivery system as just a part of nature. They are therefore fiercely against any form of volumetric water measurement at any system level. The practical result has been that they irrigate when they feel like as long as the system can deliver. They have therefore placed severe operational demands on the delivery system resulting in accelerated equipment wear and tear. Several sprinkler types have been run to destruction. Various means have been devised to reduce the wear except reducing application or scheduling. Most farmers now have a third of the required number of sprinklers as specified in design. The individual pressure regulators are no longer used. The distribution uniformity and the application efficiency are much lower than expected in the design. Designers had not questioned this in sprinkler systems before this study although earlier tests of local materials had shown problems[20]. Unfortunately, current concerns on sprinkler systems show more emphasis on simply reducing energy costs than reviewing manufacture, operational use and maintenance of sprinkler systems.

The actual variation in relative deliveries on surface schemes that takes place between summer and winter is due to the higher peak consumptive use in summer that forces different schemes to adopt different coping strategies. Organised communities with stable water deliveries and capacity to be flexible across blocks - like Deure - adopt deficit irrigation by shortening delivery period per farmer. Winter beans receive excess water in schemes that have no direct electricity costs as noted in Deure, Mpudzi, Chakowa and noted by Makadho in most old government schemes (Makadho 1994). However in Musikavanhu this study finds that winter beans is subjected to deficit irrigation mainly as a cost cutting measure. Farmers reduce flow delivered by using one borehole and then rotate groups with water. Alternatively they simply enforce dry spells where no pumping is effected as detailed in Chapter 6. At Chakowa the rotation at peak is restricted to the head-enders as tail-enders are forced to plant late in summer as a way of avoiding disappointment.

The deliveries in winter are generally higher than the crop water requirements since the capacity of the systems is sized according to the peak requirements that mainly occur in summer. Most farmers also strive to plant as early as possible in winter so as to maximise the contribution of the summer residual moisture.

In theory, the planning water requirements of more recent smallholder schemes are based on Penman calculations and irrigation schedules with 50 percent depletion. In practice this study has corroborated Manzungu's findings that there is no irrigation scheduling at all in smallholder schemes studied (Manzungu 1999). One of the strongest arguments advanced for the adoption of draghose pumped systems is its "in-built management" (Manzungu 1999, pp35). The better water control at individual farmer level was in theory meant to enable individual crop-based scheduling. However, two problems have been observed. First in most direct pumping schemes like Bonde each farmer is supposed to irrigate as long as the pump is working. This compels farmers to apply water because it is available - that is the system is "supply based". Any schedule that a farmer or extension worker does is probably going to be

[19] At Bonde farmers irrigate fields with no crops a practice as also observed at Negomo (Makotore 2002).

[20]Local manufactured sprinkler heads had been found to have nozzle variations resulting in highly variable discharge between sprinklers of the same type (Cornish 1998 pp 88 citing Solomon and Zoldoske 1994). This has to be corrected in the industry before meaningful uniformity monitoring and evaluation practices can be effected at the field level.

based on the average schedule of the group served by one pump. Essentially therefore the problems identified by Manzungu with respect to block planting obtain here (Manzungu 1999).

Secondly for those schemes that can get water delivered on demand - as at Mpudzi - the extension staff and farmers are not practicing irrigation scheduling based on real time crop consumption. At Mpudzi some farmers use the schedules that were supplied by Agritex during training which specify sprinkler application time based on the plant growth stage. Some farmers however irrigate everyday as long as the equipment allows or just based on their own perception. Farmers are also observed to irrigate all crops in clusters with each sprinkler setting informed by the individual farmer's perception of need. This shows that what is important to the farmer is not crop specific but rather the cycles of irrigation events. This is line with the recommendation and practice at Deure where due to the different crops farmers irrigate based on simple cycles as discussed in chapter 4 (GKW/HTS/BOCHOD 1985, pp20). The net result is that the upper block cropping success is mainly due to the heavy soils that retain nutrients from leaching. In the lower block where the light soils cannot retain nutrients only those farmers who can afford to add manure or fertilise consistently can harvest any crop. Some plots are virtually leached every season because it costs nothing for the farmers to get the water and they also harvest nothing so it's almost a sport where they run down the sprinklers. This clearly shows that the concept of "in-built management" in irrigation technology really needs to be reviewed. Scheduling support is necessary for systems like draghose to be of any use to farmers whose fields are on light soils.

Heavy and deep soil profiles enable farmers to adopt long irrigation cycles. They also cushion farmers against deficit periods. This additional control leverages farmers in use of systems as noted by Mutema farmers in chapter 5. Use of shallow and light soils presents design and practical use problems due to lack of this water control component. Designs and users of systems with this shortfall need to be cushioned against excess O&M requirements for sustaining these systems. Policy makers need to appreciate this to make realistic provisions for O&M of marginal lands and soils developed for low income users. Hungwe cautioned designers against use of marginal soils unless the management is prepared to go the extra mile in ensuring that scheduling and fertility practices are raised to the required level (Hungwe, pp 109 in Blackie 1984)[21].

9.7 CONCLUSIONS: FARMERS RESPONSES TO THE MISGUIDED TRAJECTORY

This comparative study has questioned the design and hand over paradigms, and its results reinforce previous findings on irrigation system performance and field practices by Rukuni (1984) and Makadho (1984). Manzungu's (1999) assertions that there is contingent field water management and no scientific scheduling practice is reiterated for surface irrigation schemes and also found to pervade sprinkler systems. The importance of social issues in irrigation management raised by Magadlela (2000) and Vijfhuizen (1998) is flagged again. As designers reflect on relevant irrigation concepts for Zimbabwe, they need to see how a WDSS needs a MSSS, and both should be consistent with local preferences and realities, and what wider agency support can provide. To this end, this chapter closes with a review of key fields of local concern and action in the face of failing paradigms, and how farmers have coped and eventually re-designed their systems in both operation and maintenance. The final concluding

[21] Unfortunately most communal areas are in marginal areas and the water source dictates the establishment of schemes on soils of limited suitability classes B and C and S as in Mpudzi (Hungwe 1984 pp 109)

chapter looks at how these learning areas could form the base for new engineering precepts for Zimbabwe.

Water delivery security

Choices in crop production are persistently shaped by water security. Managers in the older “control” paradigm consistently reviewed their system size in relation to water availability. Under the newer “efficiency” paradigms, designers appear to have anticipated that technological control will provide water and actual water delivery seems of minor importance[22], but there is no monitoring or evaluation in place for this.

On the ground this study found that the farmers undertake a **substantial amount of pre-season plannin**g relating to the water delivery security. They get little technical support but a lot of moral support from the local extension staff. The farmers focus first as groups on the whole scheme water delivery security. Only farmers who are sure of their delivery security focus immediately on their individual plots.

They organise meetings and undertake all the physical works that are required together with government employed operation and maintenance staff where available. This practice has been documented at: Chakowa at the weir cleaning; Deure for the weir, supply and distribution canals cleaning; Mpudzi weir cleaning and Bonde weir and pump intake cleaning. The simplicity of the gravity weir diversion and canal delivery technology is the main driving force. Farmers play an increasing role as the government contribution decreases (whether by default or by design), leading to **eventual appropriation** of the water delivery component by the farmers (van der Zaag 1992). Where technology is sophisticated the farmer adopts a two pronged water delivery security approach in trying to take over.

Initially they attempt to demystify, simplify or localise the technology by on their own requesting local experts to try and undertake repair and maintenance works. Musikavanhu farmers hired a local village “electrical expert” to repair and maintain borehole switch gear without Agritex Irrigation branch or the management unit based in Mutare being informed as detailed in chapter 6[23]. The local expert was not paid in full and was required to guarantee to repair the fault within the season before getting the remaining amount. At Mpudzi an individual enterprising farmer was not rebuked by fellow farmers when he “engineered a replacement for the broken pipeline” first using pots and a small diameter hose. When he succeeded to get the water moving the whole group joined him in replacing the whole length with PVC supported on branched *musasa* tree logs and succeeded in getting the scheme back into full operation. While Agritex later came to replace the PVC with steel the farmers had succeeded to demystify the design - they had shown that local experts could effectively come up with solutions. Besides technological simplification of understanding, ‘localisation’ also involves trying to minimize costs by using local labour that farmers find easier to negotiate or bargain with. It also involves use of local, easier to work with, or more familiar alternative materials like PVC over steel.

In pre-planting discussions of winter 2002 at Bonde farmers requested performance guarantees from both Agritex and DWR with respect to payment of river pump power bills and ensuring no in-season pump breakdowns respectively. This resembled the Musikavanhu local repair case. This high level contracting involving guarantees exceeds the expectations of most government officials, who consider farmers to be ignorant of business dealings (Scheer 1996, pp 201). The main difference however is that the farmers in Bonde had got to a stage

[22] This became evident during the study when a senior official led a team to prepare feasibility studies with no borehole yield data for one scheme. The donor accepted the studies after fast tracking them. However a local private designer refused to prepare detailed designs and this called for a testing of the farmer’s borehole at the farmer’s expense. In the process the well collapsed and the bitter farmer was left in a desperate situation of having no domestic water.

[23] The involvement of the local Agritex staff in the decision could not be confirmed.

where they no longer respected the credibility of government officials and institutions mandated to service them. A similar case is detailed in Mutema when an individual farmer frankly told me that they farmers did not want to entertain any more discussions before a marked improvement was evident in the water delivery subsystem. Chakowa farmers also got into such a position over the weir repairs after the cyclone. First all previous inequities were laid bare and secondly the government was asked to take a clear lead in the repair process. This crucial **stage of engagemen**t involved farmers talking straight to government or any service provider about their expectations. They can use any means including blackmailing to ensure that they get maximum government attention. The Bonde farmers stopped work on additional blocks and threatened local Agritex staff.

Once all these stages have been passed and the situation has not changed to the satisfaction of farmers the last crucial **stage of scheme re-design** starts. This involves farmers revising cropping programs, cutting down on irrigated area and - where this in not possible - abandoning irrigation in favour of dryland production within or outside the scheme. The tail-enders of the Chakowa scheme went into this stage a long time ago as regards summer maize cropping as discussed in chapter 3. It became an established practice that tail-enders plant with the summer rains. One cannot relate this to the water delivery system performance until after a thorough understanding of the original design and the management changes that have taken place over time. The Bonde farmers abandoned the scheme in winter 1998 and it has become practice now that unless they get a guarantee for payment of the river pump bills before planting then they simply do not plant. They say openly that government officials do not lose anything from crop failure because they are not farming. They would rather keep their money than to plough, buy seed, pay booster pump bills, apply fertiliser and lose out due to failed water delivery[24].

At Mutema the farmers also went through to the stage of re-designing cropping programs as detailed in chapter 5. They changed from maize to cotton and from sugar beans to tomatoes. The rate of progression from the simple pre-season planning, appropriation, engagement and finally re-design is related much to the maintenance, ownership and the regulation and control structure.

Maintain structures and design what can be maintained

Earlier sections have shown that a lot of the water delivery security problems are related to maintenance. The schemes where farmers have managed to appropriate water delivery assets are characteristically simple technology. Examples are Deure, Mpudzi and Chakowa. With increasing sophistication of the water delivery systems a gap is observed to start and enlarge as farmers traditional and local structures fail to deliver the necessary maintenance requirements. Distrust and hostility sets in eventually resulting in open confrontation as the scheme fails to deliver water as discussed in Mutema and Bonde in chapter 5 and 7. The main source of the gap is that sophisticated structures require increasing levels of technical skills to repair, maintain and replace them not normally available in the locality. Where simplification is possible technologies become “tamed” and are sustained. Farmers have generally not been able to grow fast enough to bridge the gap between the technology requirements and the available skill. Keller says they have to trade money and skill for labour that is they need money and skill not labour for modern system maintenance (cited in Cornish 1998, 19).

So far, agency designers have not been able to use the local stock of skills and materials provided by the local industry, and local industry has also not been in tune with the new technology requirements and manufacturing standards of the sector. The later is due partly to minimum involvement of the local industry in design processes. Government designers have

[24] In fact there was a case in which government was being required to compensate farmers for failed water delivery that made it impossible to repay input loans. The legal system was seeking clarifications relating to ownership issues of the development when this study started.

hardly ever handed over any design practice to any local industry, to support any evolution of services at rates profitable and feasible to either partner. This has also curtailed the development of after sales service. Government has not made a deliberate effort to create a client customer relationship between industry and the smallholder farmers using sophisticated technologies. The other contributing factor is the reluctance of farmers and farmer groups to make firm financial provisions for the purchase the appropriate skills, spares or replacement materials needed to sustain water delivery by sophisticated technologies. One major cause of this is confusion in the ownership structures.

Ownership structures

Table 9.5.1 and 9.5.6 show that roles are not standardised and unclear in virtually all management components: this stems from confusion and lack of clarity on ownership. Where the farmers can sustain the system using the traditional labour and simple material mobilisation, the unclear ownership structure handed over does not become a liability. With increasing sophistication the need to outsource skills and material places a heavy and unprecedented demand for clear ownership structures. The need to ensure fair, transparent contributions and impose sanctions to those failing to meet required financial obligations again flags the need for clear ownership structures and relations of responsibility. The need to enter into business-like repair and material procurement deals as well as out-sourcing of maintenance involves funds and guarantees, and further emphasises the need to be clear on asset ownership structures. Farmers remain confused between a state paternalism that both fears for farmers and distrusts them (that they become indebted or may even sell off public assets like their sprinkler equipment to deal with debts) – and a new rhetoric promoting smallholder farmers' innovativeness and self-actualisation (Pazvakavambwa, pp426 in Blackie 1984). There is need for government to make up its mind as regards ownership of water delivery systems and its components, and its belief in what farmers can manage at different levels of technology. The appropriateness of management and maintenance structures is importantly determined by the ownership structures, needing categorisations and ownership structures based on the communities or group capacity to retain and manage technology assets. These categories can form the basis of establishing levels and type of government assistance to be availed

Regulation and control

The irrigation sector in Zimbabwe as a whole still lacks a regulation and control culture that is supported by smallholder farmers, or that will even explain new policy interests to them. Farmers have seen how their systems have been developed without good attention to available water or groundwater supply, or the possibilities and realities or river regulation by dams. Schemes have also been developed without real attention to changes in water intake by systems upstream of them. A lack of this macro-level attention to improvement of water allocation means that farmers find no reason for adopting high level of infield water management to save water that is later returned back to the river and lost down the main river anyway. The Deure River is diverted to serve both Bonde and Deure farmers with all excess flow from the two schemes flowing into the large Save River.

This study has shown farmers taking a tough line on payments for water and maintenance except where they see a service, and profitable livelihoods to cover costs. These uncertainties help to build a mistrust of water measurement and financial documentation they might see used for external purposes – even though such measurement might help the everyday working of IMCs and system maintenance. Where necessary, farmers share scare water supplies on a time base, rather than resorting to flow measurement. Designers have also not considered measurement as something to be built into design of smallholder irrigation systems below an intake – perhaps because allocated water right itself was based on a notional demand for irrigating maize, that the state thought it could control through earlier catchment monitoring. While there has been agreement on the need for more local management and more responsibility on system abstraction and use, this study confirms works done by Makadho (1994) and others that there is no measuring culture.

However, the demands of farmers cropping have changed, and so have the new demands of ZINWA and Zimbabwe Water policy for much better monitoring of water flows. So, real challenges lie ahead. In Zimbabwe there are also now decisions to charge water on a volumetric basis for all sectors. Tough debate is also coming on whether there should be dynamic stabilization of deliveries to match scheme requirements over specified time horizons which should see farmers growing high value perennial crops getting different allocation arrangements from smallholders who focus on summer supplementary maize cropping. Smallholder farmers seem unlikely to accept this until they are allowed to negotiate more on their water security.

Rethinking - both on means to measure within technology design, and on getting farmers interested to measure, and getting them to place their schemes in a basin context - is needed. This study suggests that while farmers see measurement as a means for the state to charge them more or question their rights, they will not do it. As this study has shown, farmers now build complex relations through their local political representatives to lobby for their water, rather than appealing to technical staff or designers. Perhaps this shows the failures of engineers towards the smallholder irrigation sector as much as any poor system performance figure. The system performance data given here shows that technology has not made very much difference per se to efficiency in water use: rather the performance study has been a means to explore (like Richards, 1994) the interesting, innovative and sometimes exploitative actions that farmers and front-line workers take to leverage their water delivery

8 MPUDZI: RUN-OF-RIVER INTAKES WITH DRAGHOSE SPRINKLER APPLICATION

8.1 INTRODUCTION

The Mpudzi system has some roots in the water rights and weir intakes of former commercial farms, and subsequent resettlement of these areas. The Mutare district council identified and prioritised the Mpudzi irrigation scheme for rehabilitation in the early1990s. Agritex was requested to provide technical support. Agritex completed a feasibility study in 1992. The study recommended that the scheme be converted into a gravity piped distribution and overhead application due to excessive slopes and light textured soils (Mpudzi FR,1993). In order to retain gravity supply but also find the necessary pressure for the overhead application system, two new weir sites were identified upstream of the weir used for surface irrigation abstraction, to serve two blocks of 25 hectares each. Construction commenced immediately with Danida funding. The upper block (block 1) scheme became operational in 1994 and the lower block (block II) in 1996. Each scheme has a weir, a pipeline conveyance and distribution network that operate hydraulically independent of each other. Individual farmers have a set of hoses and sprinklers that draw water from hydrants within their plots allowing them to irrigate independent of each other. At design and implementation each sprinkler was fitted with a pressure regulator that provides for its use as an independent unit. Draghose sprinkler systems are the most recent development in Zimbabwe's technological trajectory, but here are pressured by gravity rather than pumping.

At the time of the development of Mpudzi scheme Agritex had resolved to implement an FMIS. Specific design attributes had been agreed in principle for pressurised schemes that included individualised operation and maintenance of equipment at farmer level. The institutional structures for O&M of shared distribution subsystems were to be provided by farmers as necessary. However, no attention had been paid specifically to gravity delivery systems supplying water to the new pressurised draghose application subsystems, although its O&M needs are different. Rather, the concept of local management was the new starting point. The Mpudzi scheme has a reliable gravity water supply that has supported sustained continuous cropping since the scheme started operating. There is more intensive cropping in the upper block due to better soils. Night irrigation is designed for and practiced at Mpudzi. These factors result in more intensive use of draghose irrigation equipment. This makes the scheme an ideal location to study the secondary operation and maintenance issues that relate to draghose equipment use. More intensive use could indicate issues that the pumped schemes will only face after prolonged calendar time operation periods. The dominating effect of power rationing by farmers and power cuts as well as and pump breakdowns tend to reduce the rate of equipment use as discussed for Mutema, Musikavanhu and Bonde in chapters 5,6 and 7 respectively.

The chapter starts by highlighting the water resources that supply the scheme as given by a collection of old water rights that still have to be consolidated. It then briefly studies the evolution of technology choices during the design process with a look at the intake weir identification processes. Attributes of the distribution subsystem are then presented. The management support subsystem is studied for its farmer-based institutional structures, both under normal seasonal flow fluctuations and after an extreme flood. Water distribution and application practices are studied in relation to uniformity criteria as an indicator of performance. The chapter concludes with a review of the leverage required to ensure sustainability of the system as per the designer's objectives.

8.2 WATER REGIMES AND WATER RIGHTS

The Mpudzi water source has been utilised over a long period with a gradual development process as suggested by the dates of granting of the water rights given in table 8.2.1. The old water rights show that there is a fair amount of water in the river throughout the year, and this continued granting of these rights without cancellations indicates that there is sufficient reliable flow for the Mpudzi scheme[1]. The oldest water rights numbers 858 and 1851 were for winter abstraction only. One experienced ZINWA water right official explained that most the older rights were granted in winter only because they were required for irrigating fruit trees. All subsequent rights were granted as year round water rights.

Table 8.2.1 Water rights for Chipendeke/ Mpudzi irrigation scheme

Water Right No.	Year granted	Duration of Abstraction in year	Maximum allowable Abstraction Rate (l s^{-1})	Maximum Allowable Volume (m3 yr^{-1})	Old property name
3006	1950	1/10 to 30/09	15	140000	Rem of Clydesdale
4309	1955	Year round	15	140000	Rem of Clydesdale
4020	1954		11.33	123350	Butler South
5926	1961	Year round	2.83	24670	Rem of Engwa
9375	1971		11.30	147700	Butler South
9375	1974		4	52300	Butler south
858	1932	01/04 to 30/09	14	154223	Helvetia
1851	1947	01/04 to 30/09	2.66	24670	Shinda
4949	1957	1/10 to 30/09	5.6	97700	Butler South
4949	1971	1/10 to 30/09	3.5	60300	Butler South
3142	1951	1/10 to 30/09	2 cusec	1 Mgals	Butler North
2861	1950	1/10 to 30/09	31600 gals day^{-1}	0.9Mgals	Butler North
3141	1951	1/10 to 30/09	0.5 cusec	125 acre ft	Butler North
None	nil	Year round	Design 28 l s^{-1} each		Communal-Resettlement Phase 1
Source: ZINWA records 2002					

The Mpudzi or Chipendeke irrigation scheme is comprised of two independent 25 ha blocks[2]. Block 1, that is at a higher elevation and has heavier soils, was developed first. The scheme was actually a rehabilitation of an old commercial farm system in what was referred

[1] There is no gauging station close to the Mpudzi abstraction weirs; Woodlands gauging weir station number E19 Zone EM2 on the Chitora River in the same catchment has hydrological records dating back to 1966. The mean flow varies seasonally from a maximum 344 l s^{-1} in February to a minimum 9 l s^{-1} in October. A maximum flood of 42 $m^3 s^{-1}$ and a minimum flow of 237 l s^{-1} were recorded at this gauging station highlighting the variation of the flow regime, which was anticipated in the weir development processes. The number of days of no flow at the Woodlands gauging station range from 0 to 250 with an average of 57 per year indicating that flow is not always guaranteed. At Mpudzi, farmers experienced low flow in 1996.

[2] The scheme was named Mpudzi at the time of development. Mpudzi is however a place some 45km from Mutare on the Mutare Masvingo main road. The turnoff to the scheme is located here and may have influenced the naming or the scheme. The name Chipendeke seems to be gaining popularity with the scheme farmers. The local school, clinic and business that lie between the two scheme blocks are all referred to by this name. Both names will be used this report.

to as Clydesdale area and therefore no new water rights applications were made. One old abstraction weir and canal are still active although the area irrigated is much smaller. The water rights were not specifically apportioned to the two Mpudzi blocks, but were assumed to be reassigned to the new settlers. The registration process has not been done. It is therefore possible that some other new schemes upstream could apply for some of the older rights. A discussion with ZINWA officials revealed that the process of reassigning water rights is now underway under the new water permit arrangement. The scheme lies in Natural Region II that has fairly good summer rains. The 50km^2 catchment upstream of the Mpudzi intakes weirs is steep. The scheme is likely to face increasing competition for water from schemes being created or resuscitated upstream. In 1998 the British government assisted resettled farmers in the development of the old Himalaya farm irrigation scheme. There is also a wave of smallholders who are copying the Mpudzi system and developing their own systems both upstream and downstream. Already an individual scheme is now operational on the low side of the upper block, using ordinary polyethylene pipe running down the river. The other challenge to the scheme water delivery system and its infrastructure comes from the expansion of irrigation to homesteads beyond the original scheme boundaries by the current irrigators.

The practice of extending the scheme started with a few influential individuals in the upper block. These include the former upper block chairman and his enterprising neighbour Mr Much[3]. Farmers are purchasing extra hoses and sprinklers or simply using existing hoses to extend the water supply to their homesteads for domestic use and also to irrigate at home. Crops grown include sugar cane, beans, cabbages, fruit trees and maize. Another farmer a Mr Y (an Agritex employee) now uses a plot that belonged to the late Mr X a development supervisor in the Agritex irrigation construction team. Mr X had secured the plot and settled his family there. Mr Y moved his homestead further up from the lower position near the field in order to increase his irrigated land. The extension of irrigation to homesteads and other fields outside the consolidated blocks has recently started in the lower Mpudzi block. Some sprinklers are now being used to irrigate at some homesteads beyond the original scheme boundaries by the current irrigators.

8.3 MPUDZI WATER DELIVERY SUBSYSTEM

Rock-founded pipe intake weirs and gravity conveyance pipelines

The Mpudzi pipe intake weirs constitute the major system change from the commercial farmer(s) who used two concrete weirs on the Chitora River to divert flow into canals. The lower block old weir is sited on solid rock and evidently constructed out of very strong concrete is still functioning well after surviving cyclone Eline. It is less than half a metre maximum height and that is sufficient for canal diversions. Pipe diversions were provided with a minimum of one metre depth to prevent air entrapment as well as provide for a silting basin below pipe entry level. Some farmers from both irrigation blocks draw water for surface irrigation downstream of this old canal. An individual farmer who is reported to be a member of the local chieftainship also uses the old canal to deliver water to a pressurised system that irrigates coffee.

[3] He developed two other draghose sprinkler schemes on different nearby streams for each of his two other wives leaving the first one irrigating at the homestead and the family plot. The former chairman and his mother had each a fairly big irrigated plot on the riverside. These were slightly reduced by the cyclone Eline. The block chairman in year 2000 Mr Mat also irrigated fruit trees at his homestead.

Modernising – searching for "modern intakes

The major system change was based on modernization concepts of using piped delivery and distribution systems (Cornish 1998, pp3). In order to deliver water to the two blocks with closed conduits under pressure, it became necessary to abstract water at higher elevations than the old weirs. The basic instruction to the preliminary investigation teams (these mainly comprised local farmers) was to walk up the river course and identify places with solid rock crossing the whole river (*kutsvaga ruware ronoyambuka rwizi/rukova rwese*). This solid rock had to be at a sufficient head to facilitate distribution with minimum operation cost using the modern overhead application systems. The systems to be considered were draghose, conventional lateral move and - if head was severely restricting - the perforain[4]. A small waterfall with a good weir site upstream was identified on the Chitora River at Mpudzi/Chipendeke upstream of the old weirs.

However there was not sufficient head to command the field at higher elevation in the upper block. The previous farmer irrigated the fields upstream of the main road using a brick lined canal conveyance and distribution canal that is still in place. This area also has the heaviest soil with the highest clay content. It was therefore decided to consider other sites upstream in order to try and bring this prime land under irrigation using "modern systems" i.e. piped systems. A second site was later identified where a footpath and the meandering river met, with several good characteristics, also verified by a survey team from Agritex[5].

Two separate weirs were developed giving hydraulic independence to each block. Each block has a concrete weir off-take with two steel pipes each fitted with one valve to draw water to scour the weir and the other to deliver water to the field. The upper block weir shown in photo 8.3.1 is 1m high and 27m wide and has a scour outlet comprised of 2m of 150mm diameter steel pipe.

A conveyance pipe outlet lies adjacent to the scour structure but is 250mm higher. Each inlet is fitted with a wire mesh screen. The weir is 77.76m above the first takeoff in the field (Mpudzi FR 1993). A mainline AC pipeline of 1km conveyance runs initially on the left along the footpath and crosses over the lower block weir. The lower block concrete weir is about 30m wide and 1m high. It is also equipped with a scour valve and abstraction arrangement similar to the upper block. The conveyance pipeline of total 4km is initially mainly AC with a few portions of steel converting later to PVC.

Mpudzi piped Distribution Subsystem

The Mpudzi distribution subsystem comprises asbestos cement (AC) pipelines with PVC laterals taking off as given in figure 8.3.1. Offtakes comprise of PVC tees that decrease in size with decreasing flow. The offtakes also have each an isolation gate valve just below the tee to isolate each lateral to facilitate repair works in case of leakages or breakages. A lateral

[4] Perforain and other low-pressure systems are used by smallholder farmers in other areas. In Nyanga area perforain is being used successfully especially by Matema potato growers. Some Rusitu valley farmers also use them. Members of the irrigation branch do not have much experience with this method.

5 All sites had to be accessible for construction, and have uneroded rock for strong contact. The site selected had a rock bar and rapid, 'sweetening the choice as the section of the river is exhibiting weir properties of reducing upstream flow velocity and allowing supercritical flow on the downstream section. One can gauge the incoming flow if required. The reduction in upstream flow velocity is a positive factor in high flood as the structure has a better chance of surviving if well dimensioned and reinforced. The downstream side rapid serves as a developed spillway after having been exposed to severe erosion. Its hard rock acts as a perfect spillway that is not subject to undermining. Both weir sites were good: their challenges lay in the distance from settlement, and challenges to monitor sedimentation and effect its removal.

supplies water to several plotholders making it important that it is always working properly. It also makes it difficult to use the valves as isolation devices for disciplinary purposes. There are no locks on the valves because their use to enforce maintenance fee payment or other disciplinary action was not anticipated at design (personal communication with designer)[6].

Photo 8.3.1
Mpudzi upper block pipe intake weir 1

The current drive by ZINWA to enforce payment of charges for all sources of irrigation water may demand that in future some of these isolation valve designs be revisited. However, a lateral not only supplies a number of farmers: it is also located in the centre of farmer's plots making them difficult to access for regulatory purposes. A group metering approach would be ideal for Mpudzi where a water meter can be fitted downstream of the isolation valve[8]. Adequate consideration of security of water meters is required in this case unless the current attitude of the farmers to water charges payment as discussed in section 8.6 changes.

Mpudzi continuous sprinkler operation- "draghose and hose shift too".

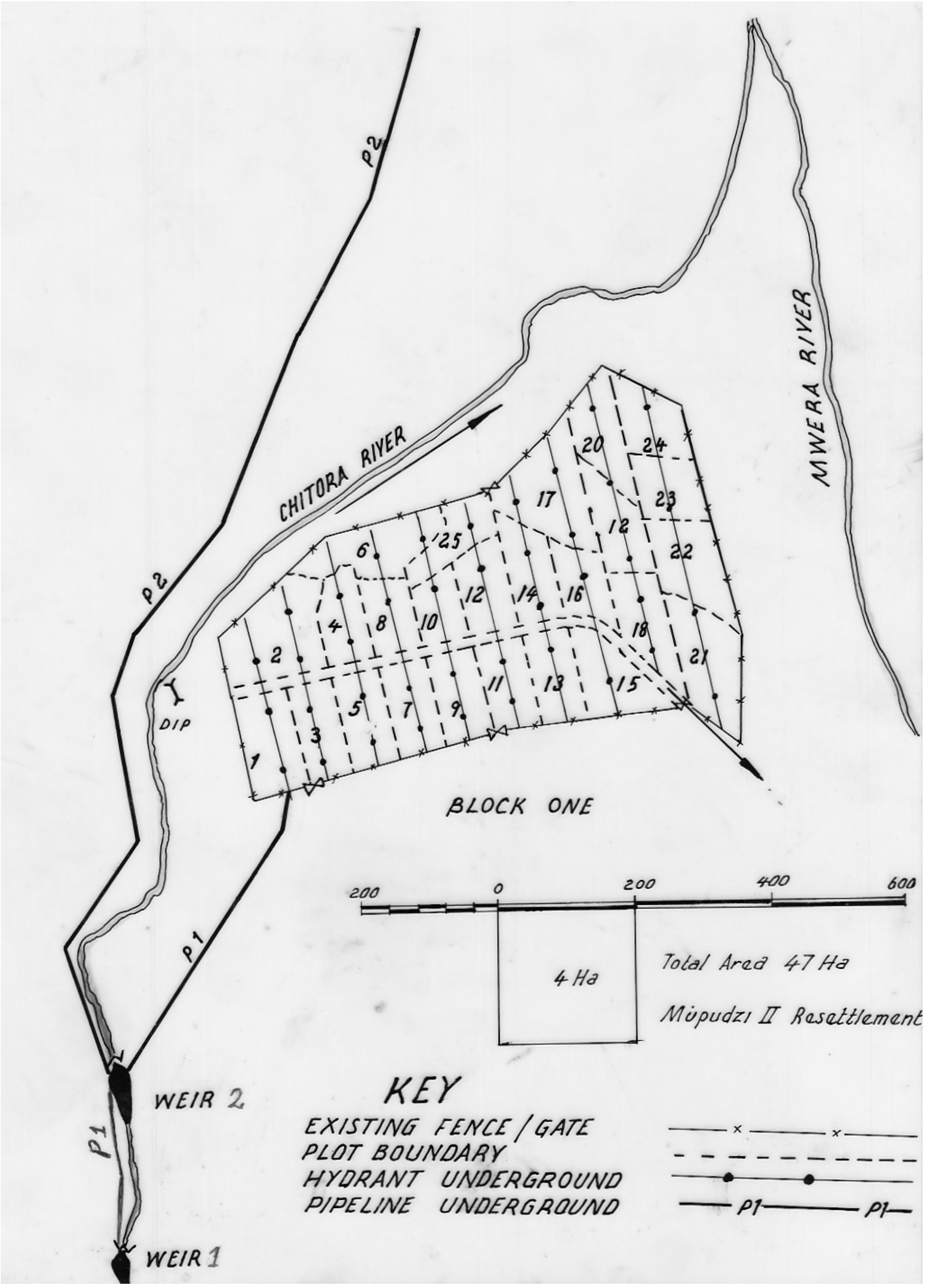
The Mpudzi irrigation scheme was designed to apply water to individual 1 ha plots with 12 hydrant positions. Each hydrant serves 6 sprinkler positions. In the process of moving the sprinkler across the 6 positions the farmer will only need to drag or pull the hose along.

[6]The Ngezi Mamina scheme in Mashonaland West has one of the most elaborate valve boxes that are fitted with manhole covers complete with locks. This facility was not deemed necessary at Mpudzi at scheme conception because of the use of gravity power.

[7]The Ngezi Mamina scheme in Mashonaland West has one of the most elaborate valve boxes that are fitted with manhole covers complete with locks. This facility was not deemed necessary at Mpudzi at scheme conception because of the use of gravity power.

[8] One would need to position control and regulation devices outside farmers plots and near access roads for ease of taking measurements and monitoring adherence to regulations or ease of control. Future designs should consider these access issues if water measurement on a plot basis is to be enforced. Experiences in Cyprus, Morocco and some Middle East states that charge for water and other services based on the volumetric water consumption suggest that there is sufficient scope to meter groups of farmers (Cornish 1998).

Fig 8.3.1 Map of Mpudzi or Chipendeke upper block (block one)



This practice of pulling the hose full of water moving over the ground is better described as dragging a length of hose pipe. This is the origin of the "draghose sprinkler system"[9]. At Mpudzi there are no hoses for the other 6 hydrants, and as a result the farmers have to disconnect the hose and sprinkler unit from the first 6 hydrants and shift then reconnect them to the other 6. This was done according to the design to reduce costs. The hose sprinkler assembly was about 25 percent of the total scheme cost. Table 8.3.1 shows the viability of the scheme under different investment and management scenarios of the hose-sprinkler units.

Table 8.3.1 Mpudzi Economic Analysis Scenarios of Difference Hose O & M

Project worthiness Indicators	With 6 hoses and Normal replacement*	With 12 hoses and Normal replacement**	With 6 hoses and Frequent replacement*
IRR	13.44	13.05	12.97
B/C	1.37	1.2	1.2
NPV	144085	131900	126907
Source: Mpudzi FR 1993*and this study**			

The designers' objective of reducing capital costs succeeded in marginally enhancing the viability of the scheme. The internal rates of return for all the scenarios are high enough to justify the scheme[10]. However, farmers have not actually kept up the anticipated hose replacement frequency. All other draghose systems installed in formal schemes in Zimbabwe under Agritex advice or designers do not have night irrigation. These systems like Bonde have 12 hydrants and 12 hose sprinkler assemblies. They therefore are not hose-move/shift draghose systems like Mpudzi. The sprinklers only serve 6 positions and are fixed to one hydrant. The problem of hose-clips was noted at Bonde but the hose-clips are no longer found at Mpudzi where they have almost disappeared. The sprinklers on pumped schemes have taken longer to wear away. They have been replaced in some schemes but at a lower rate than that experienced at Mpudzi.

Flexibility – "But within the conservation limits"

As detailed in the design each plotholder has 12 hydrant taps positioned in the centre of the field. Each farmer was supplied with 6 hoses-tripod-sprinkler units for water application. A hose sprinkler unit would ideally move across from the one end of the plot through the lateral line in the middle and across to the other end along a contour. However according to the design report:

"*A semi-portable system may have been used but under draghose the subdivision of land into different plots to be cultivated with different crops can be both parallel and perpendicular to the lateral, thereby providing more flexibility to the farmer …… By making available to each farmer 12 turf hydrant positions a flexible system of a farmer's plot lying in one part or different parts of the field is facilitated*" (Mpudzi feasibility and design report 1993, section 8.2.1and 11.1).

The design attributes imply that farmers can have different crops on either side of the lateral and also at different hydrant supply position. In practice farmers are limited by the slope to ploughing parallel to the contour perpendicular to the PVC laterals. This limitation is a conservation measure due to the steep slope in excess of 5% for blocks at Mpudzi. Experience at Mpudzi and other schemes have shown that this conservation requirement is normally met by working with extension staff members, although this has required special attention at other draghose sites like Negomo and Chimhanda.

[9] Keller and Bleisner (1990) described the system as a garden hose-pull system with potential adaptability to smallholder farmers.

[10] The discount rate used in all cases is 9.75% consistent with the interest rates at that time.

***Flexibility** –with the "scud" the pressure regulator*

Due to the slope at Mpudzi (in excess of 5 percent) the design used a number of different sizes of PVC laterals to reduce the pressure difference. The different pipe diameters necessitate that good as-built pipe detailing be always on hand in order to facilitate repairs in case of pipe bursts. Even though these different pipe diameters were used there was still a lot of pressure differences at different hydrants. This pressure control situation is further complicated by the use of only 6 hose sprinklers to service 12 hydrant positions. The twin valve assembly that characterised most draghose systems was not used[11].

For "finite pressure adjustments", to ensure that all sprinklers operate in the same range and to practice the flexibility referred to in section 8.5, each hose–sprinkler assembly was equipped with a pressure regulator locally called a "scud" (Mpudzi FR 1993 section 11.5)[12]. These scuds have been used only at Mpudzi smallholder irrigation scheme only in Zimbabwe. The origin of these pressure regulators still remains obscure: most Agritex personnel, including the system designer, cannot name a supplier company. The expatriate co-ordinator was given the job of sources the pressure regulators according the designer (personal communication)[13]. The farmers' practices with the gravity draghose distribution and application components and the impact on performance are further examined in section 8.6.

8.4 MANAGEMENT SUPPORT SUBSYSTEM AT MPUDZI

Crop production and marketing

Mpudzi irrigators strive to produce both livelihood and market-oriented crops as shown in table 8.4.1.

Basic livelihood crops

Farmers grow maize, groundnuts and wheat as livelihood crops as discussed for all other schemes. Early maize planted just after the frost in mid July can be entirely sold off as green maize at the scheme and at Marange turnoff or Mutare market. An early crop of groundnuts is also established at the same time. The main summer maize crop (also considered as maize II) planted in November and December with the onset of the rains meets their family food requirements. The 3-crop-per-year producers sell off this crop entirely as green maize and immediately grow another crop notably beans. One former chairman easily got his whole field cropped three times to green maize followed by two crops of beans. Others manage through peas and cabbage. A significant proportion of the irrigators grow additional or all their family maize needs in rented dryland plots. Some farmers also establish a summer tomato that

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[11]The twin valve assembly involves putting two valves and using one to set required pressure and the other to act as an on and off valve. Zawe (2000) described the use of such valves at the Msengezi schemes. At one time Msengezi farmers accepted the practice but later after the small sprinkler was replaced with bigger nozzles sprinklers they demanded access to the valve keys so that they could adjust their pressure themselves.

[12] The Mpudzi scheme was designed at the time allies led by US were at war with Iraq. Iraq was then using scud missiles against Israel. At this time the National Breweries in Zimbabwe launched a container for opaque beer which people immediately nicknamed "scud". The pressure regulators resembled this opaque beer container and Mpudzi farmers call them "SCUDS".

[13] However a senior irrigation specialist with a Mutare company had used 60 similar pressure regulars on a gravity scheme on a commercial farm: here the regulators were referred to as "doll" valves, and the supplier was a subsidiary of a South African manufacturer of the pressure regulators: the Harare supply outlet is now closed.

requires a lot of spraying against blight. Mpudzi farmers also grow wheat for family consumption and a small proportion for sale.

Table 8.4.1 Average irrigation cropping program for Mpudzi block 1 (1ha plot)

Crop	%	Planting date	Month											
			J	F	M	A	M	J	J	A	S	O	N	D
Summer														
Summer maize	36	15/07							◄	─	─	─	─	►
Summer beans	24	15/08								◄	─	─	►	
Groundnuts	24	20/07							◄	─	─	─	─	►
Summer tomato	12	15/09									◄	─	─	►
Summer maize 11		01/12	◄	─	►									◄►
Winter														
Winter beans	24	15/03			◄	─	─	►						
Wheat	24	15/04				◄	─	─	─	►				
Winter tomatoes	12	15/03			◄	─	─	►						
Cabbage	12	15/05			◄	─	─	─	─	─	►			
Peas	12	20/04					◄	─	─	►				
Winter maize	24	15/03			◄	─	─	─	►					
Source :field observation														

Commercial crops

Mpudzi farmers grow most of the crops categorised as minor in other schemes, and sell them at the Marange turnoff and Mutare market. The main commercial crops grown on the schemes are tomatoes, beans, cabbages, green maize and green groundnuts, rape and peas. All tomatoes grown are sold on the table market, there is no tomato for canning even though canning varieties predominate. Mpudzi farmers instead grow peas as the main canning crop on contract with a Mutare company. Farmers try to sustain year round production of vegetables and tomatoes.

Unlike the other schemes studied here, Mpudzi farmers produce two crops of beans - a practice consistent with those in the cool climates like Nyamaropa and Nyakomba. The second bean crop planted just after the frost is harvested in November or early December. The crop is susceptible to damage by the rains and therefore it is harvested as soon as it reaches physiological maturity and dried at home. The fields are then planted to rainfed summer crops. While the crop quality is generally not as good as the winter crop due mainly to rain damage it fetches better prices due to higher off-season demand. The crop is also bought as seed for the main crop in the bigger and drier schemes as well as summer bean production. Some farmers grow a special variety called *pfumisai* that they prefer to retain as family food because of better cooking quality. Farmers also grow *bata* (butter) beans for the market.

While Mpudzi is 70 km from Mutare like Chakowa it is 25km off the main road and therefore relies on an offshore niche market at Marange turn-off some 65km from Mutare on the highway. Before cyclone Eline damage the Mpudzi road was well maintained and facilitated access to the scheme by private buyers from Mutare and at times as far as Harare. After cyclone Eline severely damaged the road, irrigators spearheaded its repair to facilitate transport of their produce. About three farmers owned pick-up trucks that the other individual farmers hired to transport their produce to the market.

Extension services

An EW who also covers the surrounding dryland areas services the scheme. The EW residence and office is located between the two schemes within walking distance of both. The EW is an above average all-round performer who has a good grip of the farmers' production program and problems. An officer stationed at the district office provides backup to a number of other schemes like Mpudzi. The EW is not involved in the every day operation of the water delivery subsystem: that is entirely an individual farmer affair. He was only involved in facilitating sharing of low flow between the two schemes in 1996 leading to the two blocks agreeing to draw water on alternate days.

There are no government employees to perform O&M tasks at Mpudzi. The EW helps farmers in one respect. He keeps the spares for the scheme pipe repairs in his office. Some PVC pipes, valves and accessories are kept in a shed. There are some tools for repair of sprinklers. The EW works directly with the farmers in repairs to damaged pipes. The scheme does not pay maintenance fees to government.

The farmers and local staff are not in a position to monitor, evaluate and carry out the corrections to sprinklers without the aid of specialists. According to the Mpudzi feasibility report Agritex head office was supposed to support farmers in O&M intensively for six months and then less thereafter. The farmers were supposed to irrigate individually, using crop-based irrigation schedules. However there are no facilities to acquire, record and store real time data on weather changes like an evaporation pan. This study provided an evaporation pan but its recording proved problematic without any government employee to assist besides the EW. There are no provisions to hire any local staff to carry out functions of a monitoring nature. The EW or any government official has to solicit volunteers from farmers for any activity that requires attention.

At Mpudzi during the study period there were no operational fees paid. The scheme has no clerical staff and the farmers do not seem interested in that service since they do not have operating costs.

Irrigation management committees

Mpudzi irrigation scheme had two IMCs at block level established during development in 1994 and 1996. The IMCs had independent hydraulic units and therefore operated independently of each other. Most of the upper block farmers have close family ties and it has a core of hard working ex-freedom fighters. The lower block is more amorphous and has a bigger proportion of husbands or male household heads working away as discussed further in section 8.5. At Mpudzi the committees had not changed since the schemes started operating. Elections were held twice in both blocks resulting in changes of office bearers during the research period.

When cyclone Eline damaged conveyance pipes for both schemes a joint committee was formed to spearhead the repair process. An informal discussion with some of the joint committee members revealed that the farmers had agreed to form a combined committee to satisfy the SISP donor conditions for participation. The farmers themselves did not feel the need to have a joint committee. The SISP co-ordinator later admitted that the "marriage of convenience" was later found to be unnecessary and the two blocks are once again separated along hydraulic lines. IMCs at Mpudzi mainly perform functions related to the management of the hydraulic system. Marketing is mainly done individually, or special commodity production groups form as and when necessary.

Water Delivery Functions of IMCs

There is very little formal organisation related to the operation of the delivery system when there is adequate flow. Individual farmers irrigate independently. There is no IMC monitoring of individual operations, and weak Agritex contribution in scheduling has led to continuous operation of sprinklers. This leads to high sprinkler wear, nutrient leaching and waterlogging. During periods of peak demand or low flow - that is low RIS - the upper block farmers organise the scheme into an upper and lower hydraulic group. The upper group is mainly comprised of plots upstream of the road. The groups then irrigate on alternate days. The lower block has never been fully cropped and therefore water shortages have never been a significant issue.

Infrastructure Maintenance Roles of IMCs

The farmers in both blocks co-operate in desilting the weirs and looking after the main conveyance line as discussed in section 8.5. The distribution subsystem currently requires low maintenance for the buried pipeline network that delivers water to individual plots. Both the Mpudzi scheme blocks make no financial provisions for maintenance. Agritex and the a "donor" bailed out the scheme when it was struck by the cyclone[14]. In a discussion recorded prior to the cyclone the then vice chairman for the upper block confided in the researcher that they made false claims that that they had maintenance funds to government officials. The truth being that they had nothing ("*Munoziva vaChidenga tinokuudzai kuti tine mari yemententenzi nokuti muri mushandi wehurumende. Chokwadi ndechekuti hatina chatinacho"*). A farmer in the lower block also confirmed the same and explained that their maintenance account had been closed and funds given back to the contributors because farmers did not trust each other with maintenance funds. They would prefer making earmarked contributions as and when a need arises.

The monitoring and enforcing maintenance and repairs to equipment like pressure regulators, hoses and sprinklers in gravity systems presents problems because: (1) while maintenance is actually a cost to farmer (2) the effects of not maintaining are not felt directly by the individual farmer alone. The effects on the hydraulic performance of the system are beyond the comprehension of the farmer and the local Agritex staff. There are no facilities for measuring equipment wear. There are no guidelines to show farmers the limiting levels of leakage or the sprinkler nozzle size at which the system performance becomes adverse to the individual application or group water distribution. Farmers buy and replace individual equipment when they feel that they are being inconvenienced in some way. They purchase what they want from anywhere. They are not compelled to use the spares they buy. They really act independently with no guidelines, rules or regulations. No one has an obligation to check on the individual farmer's maintenance practice.

Traditional Leadership, Local Government and DWD

Unlike all other schemes in this study the role of the traditional leadership at Mpudzi seems completely obscure[15]. Individual farmers at Mpudzi let out plots to surrounding villagers. A discussion with one civil servant confirmed that the lower block offered lower rates but there were few takers due to the sandy soils. Most of the people who at some time rented plots in the lower sandy block stopped because the enterprise was uneconomic.

Local government identified and facilitated the initial development of the Mpudzi scheme and they were involved in plot allocation. They then left the production aspects to Agritex and the farmers. The DWD was not involved in Mpudzi at all. They are trying to come in with water charges as ZINWA. Farmers view the initiative by the DWD as just "rent seeking" without prior investment.

[14] Incidentally the same donor that financed the scheme development was financing the SISP program under a different arrangement.

[15] Perhaps this is the effect of more recent settlement by freedom fighters and a variety of ex-public employees. A traditional leader was only mentioned after cyclone Eline when farmers wanted to give him the old pipes to repair his damaged system.

8.5 MPUDZI WEIRS AND PIPELINE MAINTENANCE PRACTICE

Desilting pipe intake weirs – *high flow desiltation not women's job*
In periods of low flow, the Mpudzi weirs become perfect sedimentation ponds. Their small relative size in terms of throwback and height of wall results in the sediment filling the weir basin quickly. Farmers from each block maintain their weir independent of the other. According to the farmers the upper block weir site can go through a summer season without silting up completely. The lower block weir site virtually fills up with sand and other sediment every summer. The farmers therefore have had to desilt the weirs at the end of the rains in March and April. At this time the river flow is still fairly high and the hydrograph is still at its highest for their cropping. Flush out valves that are normally open in summer to facilitate self-flushing may in some cases save the farmers from the hard task. In the event that the desilting has to be done a Mr Mah who was at one time the joint committee chairman expressed dissatisfaction at this operation. Desilting has to be done when the river still has a strong flow, requiring that people physically go into the water-filled ponds with shovels and buckets to take out the sediment. Besides the danger of being exposed to natural dangers like snakes the job is just "not good for women" (*harisi basa ravakadzi*) according to Mr Mah[16].

He wished that the lower block had as many men or boys as the upper block weir. According to him the upper block has more men resident on the scheme and for them the desilting exercise is easy. The upper block former block chairman and his vice confirmed this. They simply call on their men only team and in one or two mornings the exercise is complete. The lower block according to Mah is a women's block. Most of the men work in town. They come during some weekends but if they do come out "their women never let them stir out of their homes" (*Vakauya havabvumidzwe kubuda panze*). He meant that the men never had time to inspect the irrigation infrastructure in their own fields or the shared components like the supply pipeline and weir. Therefore it was always the few of them (and at that time he could hardly name 7 men out of 25 plotholders) who were responsible for the men's job of desilting the weir. Mr Mah did not allude to obligations on the plotholders to clean the weir. (In Deure families or plotholders have obligations to provide labour -whether self or hired - due to their strong management and the need to meet specific maintenance dates.) The organisation of Mpudzi lower block farmers seemed weak, perhaps also due to the lower economic returns in this block.

Flush-out valves located at low level in both weir walls are functional and normally left open in summer. In winter the valves are normally closed and only opened frequently to flush out sediment. No one is permanently appointed to operate them. However there were three alternative teams in the upper block that were responsible in weekly time periods to look after the weir and pipeline.

The teams report to the block chairman. Each has a team leader who should have participated in the original scheme construction. During their term of responsibility the team members are expected to operate the valves and undertake any minor repair or maintenance work like removing logs and other debris from the weir that might clog the pipeline. The team spearheads the mobilisation of extra labour for any major works that arise during their turn. The structure seems to derive its strength from the strong leadership of the then chairman, a former freedom fighter and the strong family ties of the group also revolving around the chairman. In the lower block no clear organisational structure existed.

[16] Mr Mah description of the task was very similar to what Manzungu described at Fuve Panganai, with reference to farmers having to go into and even under-water to clean operating valves.

Impact of cyclone Eline on the Mpudzi weir intake

The Mpudzi weirs survived cyclone Eline. Some damage was done to the right side supports on the upper block weir. The researcher had observed the weakness before the cyclone and notified the farmers in 1998, but nothing was done in 1999. The cyclone further exposed the foundations and some water was leaking at that point. The lower block weir was intact but had a section chipped off at the centre that required some patching up. The cyclone silted up the whole weir. The farmers managed to clean both out. The outlet valves for each block were working well and both survived the cyclone. However the galvanised iron trash rack at the pipe inlets seemed worn out and torn due to rust. There were no plans to replace them using the spares provided at development.

The pillars on the weir- cyclone experience-pillars barrier to logs

The pipeline for the upper block is suspended on pillars forming part of the second weir intake. This was based on trying to take advantage of the second weir and construct pillars on to which to hang the steel pipes[17]. The pillars themselves were placed about 5m apart and as a result the steel pipeline could not support its own weight and water. The pipeline therefore tended to sag until it was reinforced using steel bars. The pillars are not firmly anchored in rock. Although they are huge mass structures as shown in photo 8.5.2 one can easily see the foundation sitting on loose material. The researcher alerted the EW and vice chairman in 1999 of the need to seal the gap developing at the toe of the right most pillar or it might give-in but no attention was given. During the cyclone logs hauled down the river hit the pillars and pipelines: these gave in and all but one pipe length were washed down the river.

Photo 8.5.2 Farmers' reconstruction upper block -PVC on pillars reinforced with Msasa tree logs against sagging at Mpudzi

[17] The Mpudzi feasibility report anticipated the "violent floods" and specified for a riverbed crossing with extra reinforcement specifically aimed at holding the pipe in place during floods (Mpudzi FR 1993, section 11.4.2). The actual construction was then based on the economics of using the weir as anchorage. The pipeline itself was never specifically held in place against floods and had been reinforced due to the sagging of the water filled pipes. That Agritex requested for the structure to be reconstructed as before shows again a case of reactive decision making without taking time to get to the bottom of the problem.

The right-most pillar that had already been undermined also went down the river. The pipes were found near the old weir to the lower block. They had been bent and battered. Some steel pipes at the inlet were also washed down.

The farmers teamed up with their lower block counterparts and immediately informed Agritex seeking help. When Agritex was too slow to respond they approached the European Union (EU) Microprojects but failed to get assistance. Agritex eventually considered their request and supplied the steel pipes as requested. Unfortunately the reinforcement was not included in the farmers' request. The farmers and the local Agritex extension staff most probably did not appreciate the need for the reinforcement or they simply forgot to request for it. The upper block farmers undertook to provide cement and stones required to reconstruct the pillar that had been washed away but failed.

Farmers' reconstruction initiative-reinforcing PVC across pillars with tree logs

Farmers managed to replace the steel pipes near the intake with the new pipes supplied by Agritex. As for the steel pipeline on pillars they never attempted to use the steel pipes themselves. The enterprising farmer, who had engineered his own two schemes and spearheaded homestead extensions, then first experimented with the use of 50mm hose pipe and joining it to either end of the remaining pipeline. He reduced and adapted the 150mm diameter steel pipes to the 50mm diameter black polythene using old pots and tied using plastic, rubber, tree bark and wire. The hose was actually passing through water in the weir. Water started moving down the pipe but in small quantities. This excited the other farmers who decided to use the PVC lengths supplied by Agritex as spares at construction. They laid them over the remaining pillars. For the end joins they used plastic, tied with tree bark, rubber and wire. Adapters from steel to PVC were made of plastic and old pots or tins. The pillar that was washed away was not rebuilt and therefore the pipe was sagging due to the long span. They then took local Msasa tree logs and supported the PVC pipe, see photo 8.5.2. The PVC pipes were joined together with solvent cement.

Although there were visible leaks the water flowing through the supply increased substantially and irrigation started. Farmers stopped talking about repairing this supply line component of their system. They had found that the local equivalent of reinforcing a steel pipeline with steel by just supporting a PVC pipe with logs worked just as well.

The steel pipes - that they say were damaged beyond repair - have been panel beaten and now provide a gully crossing to the old canal for the coffee grower. It is understood that Agritex later gave a directive for the steel pipes to be reinstalled under their supervision.

The lower block – New gullies after cyclone – "hang PVC on wooden stands"

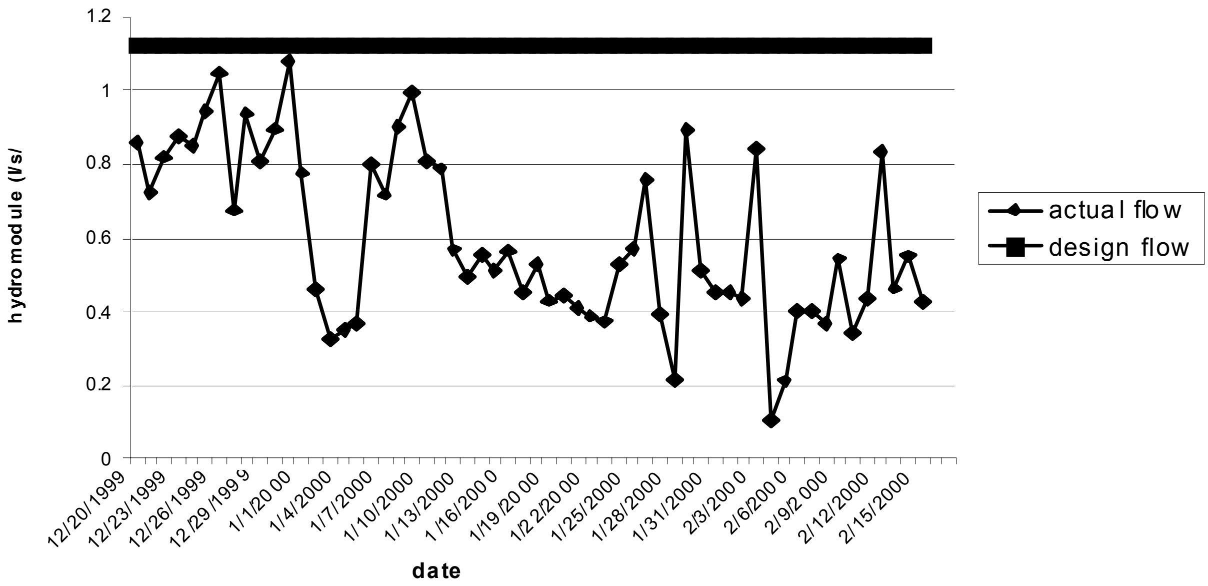
The lower block had problems maintaining the old 4 km PVC line due to frequent pipe bursts. They took longer to attend to the bursts as the few men had to organise and walk all the way to effect repairs. The cyclone opened up three new gullies on small streams. The uppermost gully was a small stream that has been widened. The farmers simply joined PVC pipes and supported the lengths with wooden pegs with branch (Y) at the top end from where they simply hang the PVC pipe. The second gully had originally some steel pipe enclosed in a brick casing. Again they used the same trick. The last point is the road crossing where the PVC had been left in the road gully. The PVC had been kept aligned by anchoring with some tree branches. Farmers were getting the water and they seemed happy with the arrangement. In fact there were no leakages in the lower block PVC line. Neither group used the consignment of new steel pipes they had ordered on their own. There is no road navigable by vehicle to the weirs. During construction all the materials were carried up by human labour. Most of the labour was paid on contract including those who were going to the beneficiaries. Those who worked in the construction claim to know how to carry out the repairs as stated in the requests they submitted after cyclone Eline. Their capability to repair leaks on PVC pipes have been tried and tested in the supply and distribution leak repairs for the lower block and in the infield distribution repairs for both blocks. The farmers on their own do not like working with AC and steel in their water reticulation. Maybe they do not have the skills required to work with the material or they simply do not find any meaning in carrying heavy steel pipes if the same result can be obtained using light PVC pipes. A technology gap might exist as pointed out by Horst (1998).

Agritex in late 2001 made a directive to repair the cyclone damages at Mpudzi. The Agritex officer who was responsible for the initial scheme design and initial construction supervision in 1994 was called in to supervise the rehabilitation after cyclone Eline damage in 2001. The rehabilitation was sponsored by SISP as it was one of the pilot projects. Unlike the initial development, a Mutare-based contractor was hired to do the rehabilitation. All additional fittings, including the steel reinforcement pipes and cement, were bought by SISP. The farmers were expected to contribute up to 15 percent of rehabilitation cost under the SISP programme arrangements. The supervisor noted that their contribution never really got to that mark. In his view they were generally uncooperative and they raised a lot of “unnecessary” issues. This forced the contractor - a former Agritex irrigation branch employee - to hire most of the farmers as contract labour in order to “forge” ahead (personal communication). The pillar that had been washed away was reconstructed. The pipes were put back in position as in the original design. Some of the issues raised by the farmers as given in box 8.6.1 were also addressed according to the Agritex officer.

Box 8.6.1 Problems of being senior Agritex development officer and researcher

Chipendenke irrigation Phase I meeting 16/12/1999. *Zvichemo zviri kubva kuvarimi pamusoro pezvaifanirwa kunge zvakaitwa pakugadzirwa kweirrigation*, (requests from farmers as to what should have been done at the implementation of irrigation).
Implement shade – foundation built
Mesh wire – all around scheme told that it was already bought during the construction.
Agricultural inputs – for start up financiers donated
Spare parts include hose pipes, sprinklers spares, wheelbarrows, pick-axes and shovels, PVC pipes
Toilet cements
Protected drinking water – line to be diverged from the main watering line (catchment tank to be built)
Weir construction incomplete – base level and supporting pillars all around
Chichemo (request) – Transport *takagara tichikumbira kuti titengerwe motikari* (we have always requested that a vehicle be bought for us).
Branching valves (along the fields) not protected *kuvakira maboxes nezvidhina* (to built brick boxes around)
Flashing valves – at the fields ends (branching lines)
Kuvakira kwematapes (the protection of tapes)
Storm drain proposed but not built.
The list of requests was according to Mr. Zhakata, who was leading the team installing the water meters, a compromise and almost a set of conditions to be fulfilled by Agritex for them to successfully meter the block. The team did not manage to install the meter on this day and requested that I join them to avoid any delays from farmers not cooperating or asking questions. When we went together I paid a courtesy call to the chairman and he did not refer to the request note. The vice chairman come to chat with us during the water meter installation after we had called on him. The local EW was with the Agritex team throughout the exercise. The farmer leaders did not even remind me of their request letter. I also did not refer to it. This is one instance where studying situations where you are directly involved become dicey. Fortunately I had a research assistant resident at the scheme who helped in capturing and observing during installation the view of farmers and government officials like the team, Mr. Zhakata and myself. The suspicion and lack of care for this water meter is a problem.

Fig 8.6.1 Mpudzi flow records



These included provision of flush out valves and construction of valve boxes. The issue is whether Agritex convinced the upper block farmers to replace the PVC pipes with steel or the farmers simply accepted it as another top-down technological intervention.

8.6 METERING RECORDS AND SYSTEM PERFORMANCE STUDIES

Earlier water meters were only installed as a legal requirement to get a final water right. They were never used for monitoring water use by either farmers or Agritex. Occasionally or during arguments the hydrological section of the DWD (currently data management under ZINWA) use water meters to the determine flow. The designer of the first block admits that he did not include a water meter in the bill of quantities. Some of the upper block (block 1) farmers confirm that there was talk of a water meter being installed in the their block. They even pointed to where the water meter was supposed to be but for some unknown reasons it was never installed. Interestingly the construction supervisor Mr X was allocated a plot in this block. The second block was developed about a year later and a water meter was installed at the field edge but it was fenced out of the scheme and never covered. The water meter for block II was never used for recording use of water until an unsuccessful attempt was made under this study to use them to monitor delivery to the two blocks (where a meter was in place for Block II).

A meeting was held with the farmer leaders and the EWs to initiate flow recording. The farmers did not object but they did not take the readings. The EW started taking the meter readings. Within a week the meter glass had been damaged and nobody was charged. The project took the meter for repair and brought it back and installed it at the same time as the new water meter for block 1. However no clear flow measurements were effected in that block.

The block 1 farmers are clear and open about their lack of interest in water metering. They regard it with suspicion. When trying to install the upper block meter for this study there was very little co-operation. The farmers and their chairman took the water meter installation as an opportunity to remind Agritex of a number of problems with the infrastructure that needed to be rectified. These in their view were design or installation oversights. The requests as submitted are given in box 8.6.1.

The situation was made worse by visit to the scheme by a ZINWA official. According to the resident EW he called both irrigators and dryland farmers to the business centre to introduce "his" water payment issue. The EW understands that the official did not get a good reception. During the brief meeting the ZINWA official was asked to explain why the authority wanted to charge when they had no contribution to the scheme's irrigation development processes. Farmers expressed anger at ZINWA's efforts to charge for God's gifts. The ZINWA official is said to have infuriated the locals in this area by introducing this subject that they politely asked him to leave.

Hydraulic performance

The daily water use or withdrawal pattern to the upper Mpudzi block for the period 20 December 1999 (when the meter was finally commissioned) to 15 February 2000 just before the system was damaged by cyclone Eline is shown in figure 8.6.1[19]. The meter readings show that the farmers continue to use substantial amounts of water even in the wettest periods when the crop water requirements are minimum. The fluctuating daily consumption nears the design flow in late December and remains low for January and February the wettest months of the year.

Water delivery performance

Field records of irrigation decisions show that farmers use their independent value decisions to irrigate. They irrigate at night, and in most cases the system is delivering water as required. Irrigation frequencies of 3 to 4 days are common for ordinary crops. During harvesting of peas the crop is irrigated on a daily basis. Although all farmers were supplied with notebooks and assisted in filling forms only 6 out of 25 farmers in the upper block submitted comprehensive accounts of their irrigation practice. Only 4 out of 25 were obtained in the lower block. Literacy and individual interest in water consumption monitoring structured the sample of responses obtained, as found at Musikavanhu

The farmer's individual irrigation practice records were used to calculate the average water applied to each crop. The relative irrigation supply - obtained from the irrigation times and average sprinkler discharge for Mpudzi upper block scheme - is given in figure 8.6.2.

The scheme has a high RIS in the winter months due to the generous applications given to the mainly leafy crops that dominate the crop program. The high RIS mainly applied to peas and other vegetables closely resembles the Chakowa upper block A. **This suggests that in cases of adequate water supply the farmers perceived crop water requirements (CWR) rather than technology to determine actual deliveries.** A brief deficit occurs in December due to the high evapotranspiration demand created by the large area (36%) planted to green maize. At this time period the upper block farmers divide the block into upper and

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[18] Readings were taken by a farmer (also long standing vice chairman) in block 1 with the assistant of the EW and monitored by the researcher assistant. After the repairs by the farmers in June 2000 the water meter was reported not working. When I was informed I promised to fix it. However I got busy with writing this manuscript and therefore could not follow this seemingly hot issue of attempting to meter and charge water in a farmer managed gravity system.

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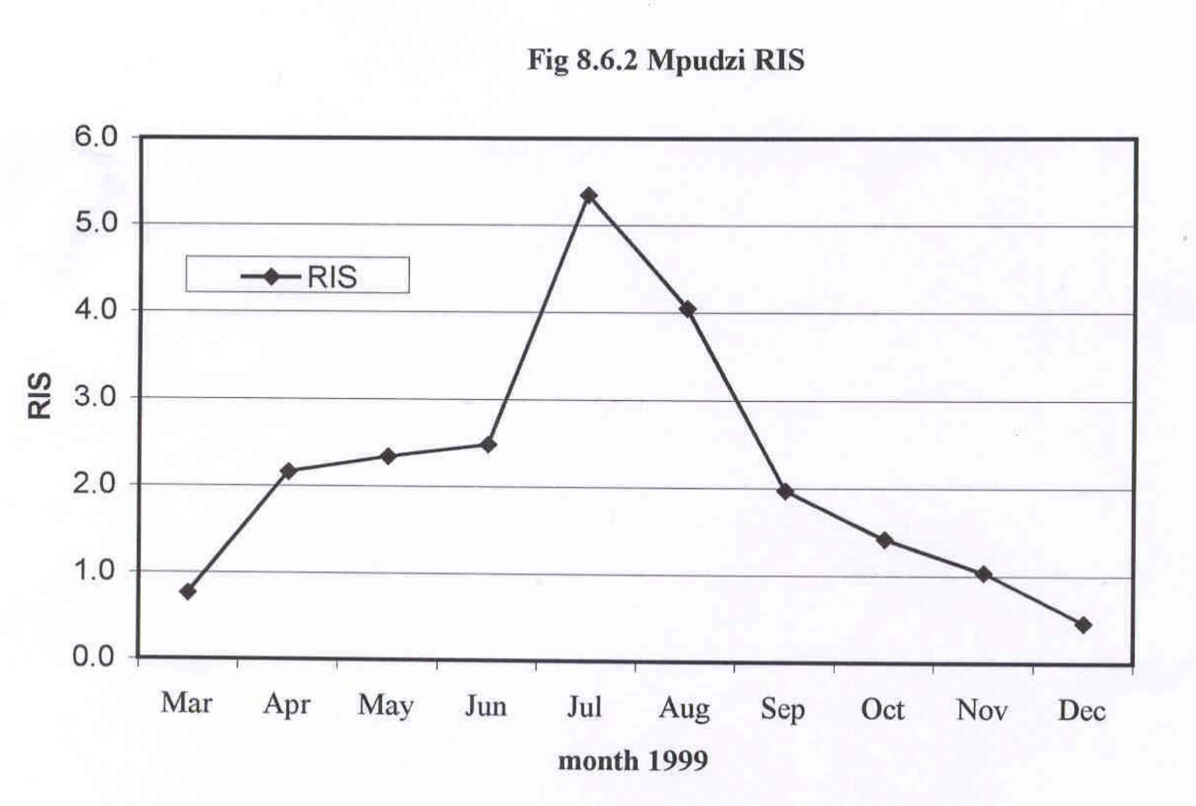
lower hydraulic units that irrigate on alternate days. This method of enhancing equity and coping with scarcity is also practiced at Chakowa and Deure as discussed in chapter 3 and 4.

Fig 8.6.2. Mpudzi RIS



8.7 PIPED DISTRIBUTION AND SPRINKLER APPLICATION PRACTICE AND PERFORMANCE

Farmers at Mpudzi have further adapted their field irrigation technology to obtain the water supply they prefer – to get higher discharges and wider radius of spray. This can cut down field time for monitoring and can help do away with night irrigation. They have also experimented to find solutions to parts not easily replaced, especially where a new assembly anyway gives them the increased spray characteristics they want. These adaptations could have brought problems into the system, but other changes also now mean that farmers use fewer sprinklers than recommended. This reduction has happened through non-replacement but also theft. While this affects the performance of the sprinklers and the system (as this section will show) it neither gets to a level of concern to the farmers – nor is it a problem they can easily work out at system level.

Infield equipment maintenance and replacement practice
The "scud" - and the ¾ inch diameter hose replacement dilemma
As described earlier, the 'scud' pressure regulators help maintain pressures in the system in ways allowing farmers to irrigate independently. Farmers have found their own ways round these devices after problems in their use. Most of the pressure regulator "scuds" are still in good working order in the lower block, where some farmers hardly irrigate at all. However they have almost disappeared in the upper block where there is more consistent intensive cropping. Most farmers say that they easily broke on the points where they must be joined to

the hoses. Once their plastic adaptors are broken it is not possible to repair and use them. Some farmers have started placing them above the tripod and connecting them directly to the sprinkler, to avoid damaging them through repeated contact as shown in photo 8.7.1. Some farmers have simply replaced the "scuds" with equal lengths of 20mm (0.75inch) diameter hose. The probable reason is that the scud to the farmers is just an enlarged plastic chamber whose inner workings they do not know. Some farmers in the upper block also claim that they failed to find suitably sized replacements for the "scuds" in Mutare.

The farmers who have removed the scud and used them with bigger sprinklers find this a satisfactory arrangement. Most of the sprinklers used are rotating impact type with varying nozzle diameters. The most common nozzle diameters are 3, 3.5 and 4mm. A few farmers have tried and quickly abandoned rocker arm sprinklers. The farmers' view is that the scud is best suited for use with the small 3mm nozzle (the designed sprinkler). The scud was also designed for a smaller diameter 12mm diameter hose. One would need to buy adaptors as well in order to continue using the "scud" with available hose. In practice farmers have generally bought the larger ¾ inch (19 mm) diameter hoses together with 4mm nozzle diameter sprinklers and stopped using the scuds contrary to the design[20].

At Mpudzi farmers are interested in increasing sprinkler discharges to cut down time spent monitoring water application and do away with night irrigation. Precipitation rates can increase from 4.72 mm/h to 8.06mm/h due to increase in sprinkler nozzle only. This might reduce set time by about five (5) hours. They also say that the new large sprinklers are less affected by wind. The net result is that farmers are now operating with larger hoses and higher discharge sprinklers.

Photo 8.7.1 A pressure regulator "scud" directly connected to the sprinkler and hose to avoid damage at Mpudzi

Hose and sprinkler replacement

The farmers' decision to adopt the use of bigger sprinklers and bigger hoses has been accompanied by lack of replacement of some hoses and sprinklers. In general discussion

[20] The designer cited use of smaller sprinklers and close spacing as advantages in the system design as follows: "*This layout also had the advantages of small diameters of hoses and risers and shorter hoses which facilitates the ease of moving the sprinkler from one position to another. In addition, the spacing allows the use of sprinklers requiring less pressure in relation to those used under the 12 x 18 m spacing"*. Note that Bonde converted to 3/4 inch hose at implementation in order to reduce operating costs as discussed in chapter 7.

farmers claim that they are replacing worn out hoses and sprinklers. In practice most of them now have fewer working sprinklers. On average each farmer now has four working sprinklers out of the original six supplied[21]. Considering the average discharge obtained in the upper block as given in table 8.7.1, each farmer has a stream of 0.26 l s^{-1} (0.94 m^3 h^{-1}) compared to the design stream of 0.19 l s^{-1} (0.68 m^3 h^{-1}). One young man who was irrigating his brother's plot said he actually now had one hose-sprinkler unit working out of the original six supplied. Three were worn out both hoses and sprinklers and had not been replaced. One had been stolen a few months earlier when he came to the scheme. He had then borrowed a hose from a neighbour to use with his brother's working sprinkler. Unfortunately this assembly had been stolen the previous day. He was therefore irrigating 24 hours a day with no rest at all.

Table 8.7.1 Field uniformity results for Mpudzi irrigation scheme – upper block

Field No.	Sprinkler Pressure (kPa)	Ave. Wind Speed (km/h)	Sprinkler Discharge (l s^{-1})	Nozzle Size (mm)	AELQ (%)	DU (%)	CU (%)
1	250.0	9.0	0.32	4	10.5	52.2	68.3
2	257.5	7.0	0.29	4	56.4	56.0	66.7
3	145.0	5.0	0.15	3.5	33.3	43.7	61.9
4	200.0	4.0	0.24	3	24.8	44.3	69.7
5	215.0	11.0	0.28	4	17.0	35.7	64.2
6	250.0	9.0	0.24	2.5	43.3	60.0	77.5
7	275.0	10.0	0.35	4	27.8	66.0	73.0
8	290.0	10.0	0.34	4.55	26.1	54.3	66.3
9	217.5	6.0	0.23	4	0.0	0.0	40.6
10	250.0	6.0	0.23	3.65	36.3	55.2	57.4
11	230.0	6.5	0.23	3.8	34.2	45.0	64.4
12	195.0	0.0	0.23	3.8	7.4	25.8	40.6
Mean	**231.3**	**7.0**	**0.26**	**3.7**	**26.4**	**44.9**	**62.6**
Design	**350**		**0.19 (0.68 m3/h)**	**3**			
Source: field measurements 1999-Mugusto.							

His major problem was lack of sleep! His lone hose sprinkler unit still had to serve twelve hydrants with six positions on each. The hose was now showing "threads" and some darkening. It had an average number of rubber strips to stop leakage.

The farmers were not keen to replace hoses. Those who have bought new hoses prefer not to use them in the field because thieves target them, and can continue to use the old hoses. Therefore not many new hoses were seen in the field except those in the lower block that were hardly used.

The primary design envisaged individual care and replacement of hose and sprinkler equipment. Therefore no institutional arrangement was provided for the co-ordinating and enforcing replacement or maintenance of infield equipment. It is almost impossible to mark hoses with codes as reported with Mutema sprinklers in chapter 5. Farmers can buy replacement hoses on the shelf in Mutare. They are stock items in most hardware shops. The draghose (hose move) and hose shift also requires a revisit on the hose life.

[21] In 1998 on average one or two hose sprinkler units were not working and these had either been replaced or were being replaced by one unit. Most of the units replacing the old one then were coming from Burma Valley. No farmer was willing to explain exactly how the traders got the sprinklers. Most popular was the rocker. Interviews in 2000 indicated that three out to six sprinkler units were not working on average.

Mpudzi farmers have also almost stopped using hose clips in favour of tying with rubber strips. The problem of leaking hoses is a definite cause of pressure loss. Farmers know this and try their best to stem the leaks with rubber. Leakages from hoses with water visibly forming jets are common. They mainly occur when the farmer is neither in the field nor at home. However leaks that just wet the local spot are most common. Farmers do not like them but they consider them as minor.

Generally hoses had an average of six rubber strips tied around each hose length to stop or reduce leakage. The major cause of leakage according to one farmer from the upper block was audible cracking that occurred in winter months only around June. Hoses only crack at the bends during change over in the cold months, and some farmers believe this is due to freezing of water in the hoses. In an earlier discussion in 1998 a lower block farmer said that the hoses were of poor quality. Actually the small cracks allow water to enter the space between the plastic layers of the hose that is occupied by the reinforcing fibre. It is this water that eventually causes the two plastic layers to separate further leading to further breakage and exposure of the fibre. Once the fibre is exposed it is a matter of time before the inside pipe cracks and the pipe starts leaking.

Heavy-duty use for the small sprinkler

The adoption of night irrigation succeeded in reducing capital costs but increased the need for replacement of sprinklers and need to monitor irrigation at night. There is evidence from the sprinkler wear that the scheme will need farmers to buy new sprinklers every two or three years. Failure to replace sprinklers and hoses has resulted in nozzles enlarging and obviously affecting the system pressure and uniformity as shown in table 8.7.1. The average nozzle diameter is now 3.7mm up from the design 3mm. The average sprinkler operating pressure (SOP) is 230 kPa well below the design SOP of 350 kPa. It is however marginally lower than the 260 kPa recommended for the 3mm nozzle in the old irrigation handbook (Pilditch 1974, pp9). The indoor tests at the ZITC also confirm good uniformity for the same nozzle around 250 kPa SOP suggesting that the farmers' practice of reducing the SOP is not at fault.

Farmers generally expressed displeasure at irrigating at night on a continuous basis. While some systems such as Deure use night irrigation to enhance system flexibility, at Mpudzi night irrigation is a requirement as the system was designed for two shifts of 12 hours each (Mpudzi FR 1993 section 11.3). This effectively means there is no flexibility to cope with situations of demand higher than predicted at design. Farmers' reaction has therefore been to enhance system discharge through replacements with bigger hoses and bigger sprinklers for the same spacing. The other factor that accelerates wear of the sprinklers at Mpudzi is its highly reliable water delivery. Since the development of the Mpudzi irrigation scheme, river flow has only been lower than demand for one or two months in only one season according to the farmers. The upper block farmers with their better soils successfully kept the land cropped and productive for most of the year. Rains defines the slack period although there is still a fair use as shown in figure 8.6.1. Immediately after the rains in March or April the water delivery subsystem system literally runs non- stop until the next rains especially for the good farmers who squeeze in three crops.

The upper block has very few of the original 3 mm nozzle diameter rotating impact sprinklers still in use. In 1998 it was already becoming evident that the sprinklers were getting worn. This continuous "working" without the Mutema – Bonde type maintenance "rest" and electricity "refuelling" breaks, have given the 3mm nozzle sprinkler a tough time at Mpudzi. The major weakness was the sprinkler impact arm that was breaking due to "work". The farmers tried to prolong the working life of the little brass arm by tying tree back and plastic around the arm or sprinkler so as to reduce the impact. This practice was popular in 1998 but died away in 1999. A new approach of using the rocker sprinkler - that did not use a little arm hitting on the sprinkler body - was tried. Box 8.7.1 gives a case study of Mr.

S., a young farmer in the upper block, that highlights some of the dynamics of maintaining and replacing sprinklers at Mpudzi.

Water distribution and field application performance

Table 8.7.1 summarises field application uniformity and performance of the upper Mpudzi block[24]. The data was obtained from catch can uniformity tests in 1999[25]. Wind speed measurements were initiated. The findings show that generally the system is operating at an average pressure of 230 kPa that is far below the design pressure of 350kPa. As mentioned before the average sprinkler nozzle diameter of 3.7 mm is far bigger than the design nozzle of 3mm. The unit sprinkler discharge is far higher than the design sprinkler. Generally the uniformity is not good with an average coefficient of uniformity of 62.6%. The main causes of poor distribution could be low pressure, wind, nozzle differences, and leakages.

Table 8.7.2 Comparison of design and actual wind speeds at Mpudzi

Month	Design Wind Speed (km h^{-1})*	Actual Wind Speed (km h^{-1})**
December	5.2	10.7
January	4.9	6.8
February	4.3	9.8
Source: GOZ/AGRITEX, 1993* and field observations 1999*		

[22] This block is more active and productive than the lower block. Farmers cite the light soils that are inherently of low fertility and are also prone to leaching. When we visited the scheme even my promoter Prof Linden Vincent said; "*these are almost acid washed sands*". In contrast consultant – agronomist, practicing horticulturist and technical expert from Israel, Mr E T is more interested in working on sands with drip systems. The draghose system was adopted to enhance performance. Soil fertility also seems to be a strong factor in system performance. Observations at Chakowa block C and D, Deure A and D and Mutema sandy block do support this suggestion. For this reason the upper block system performance was accepted as a good site to monitor the installed infrastructure performance under optimum use conditions.

[23]The performance was test done by a research assistant Mr. D. Mugutso who was an undergraduate student in Agricultural Engineering. During the irrigation period in 1999 he stayed at Mpudzi and monitored irrigation operations. While staying closer to the lower block he monitored more the upper block because of the higher level of activity. Catch cans were made from 500 ml motor oilcans and placed in grids to monitor performance. Nozzle diameters were measured using vernier callipers.

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Box 8.7.1 Mr. S and the rocker sprinkler test

Appendix 8 details Mr. S's sprinkler operational practices in the winter period from March to early August 1999.

During this time the farmer typically grew typical early sugar beans (0.4ha), peas (0.4ha) and wheat (0.2ha). The records show that the farmer practiced frequent irrigation with a calculated average interval of 2 days. Beans got 11 irrigations excluding the harvest "kudzurisa" as compared to other schemes with 4 to 5 events. This was due to some occasions when the bean crop received almost daily irrigation in the period 15 April to 28 April to "ensure proper flowering" followed by daily daytime irrigation against sun scotch. Peas got 17 irrigations in 3 months. There was frequent irrigation during flowering from 27 June to 14 July followed by daily irrigation during the harvest period from 5 to 12 August.

Most of the irrigation was done in clusters with the farmer going through all crops during an irrigation event. These irrigation events include night irrigation. There were also defined dry days from 16 to 19 May, 24 to 26 May, 9 to 13 June, 17 to 19 June 21 to 24 July when the farmer did not irrigate. Here they are occasioned by the individual farmer's desire to “get out of water for a while” (*kumbobudawo mumvura*). The farmers would rather irrigate at night and close off the system than engage in continuous irrigation.

Generally all crops received part of their irrigation at night with the least being beans because it was earlier than the other crops. Although the area grown to wheat was smaller it had more night irrigation events than peas. This is probably an agronomic issue of trying to reduce fungal diseases by irrigating at night.

After the initial “small-Agritex ” sprinkler got worn out in less than two years Mr. S. bought the “rocker” a sprinkler that was fundamentally different from the others. The slower - and according to Mr. S,- more majestic action seemed to do the trick. In 1998, the new acquisition was giving him in his view better throw, higher discharge and no wind distortions. He then did not need to irrigate through most of the night like his neighbours[26].

However within a period of two years in October 2000 his mood was different. He showed the remnants of his rocker sprinkler. Thee Mpudzi endurance requirements had also exposed the weaknesses of the rocker. As the sprinkler rocks the axle cuts through the brass body the vertical groove created increases until the axle no longer returns to the jet. At this point the sprinkler stops deflecting and according to Mr. S beyond repair[27]. So within two years Mr. S's rocker got worn beyond repair. He then bought the common 4 mm diameter nozzle impact sprinkler. While acknowledging that it has a better diameter of throw, bigger discharge and better performance in windy conditions he is no longer excited by sprinkler performance. He simply says that the moving parts on these sprinklers tend to wear very quickly. His question is whether there are no sprinklers with no moving parts “*Ko hakuna here maspringira asina zvinofamba zvinokurumidza kupera”*. Few smallholder sprinkler users in the formal schemes have asked this question before[28].

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[26] “*rocker inosvitsa mvura kure, inopa mvura yakawanda, hainyanyo vhiringwa nemhepo. iko zvino ndinopedza kudiridza nguva ichipo handicharara mumunda. kana usiku uchidiridza unotomuka usiku hwacho kakawanda uchiona kuti ma sipiringira ari kusevenza zvakanaka*”

[27] I could not establish a company that offers spares and repairs for rocker sprinklers. The company that used to manufacture them was sold to a company that is retailing different impact sprinklers. For spares I was referred to an individual who I could not contact on the phone. Designers of sprinkler systems associate rocker sprinklers with ARDA that was once the main buyer of that sprinkler.

[28] I explained to Mr. S. that there is a floppy sprinkler developed in South Africa has not been widely adopted in Zimbabwe. At Kanhukamwe/Negomo a Nelson R2000 rotator sprinkler fitted with a 1/8-inch nozzle that does not use the principle of the impact or rocker has been introduced. However studies done at the scheme reveal that 66 percent of the sprinklers are malfunctioning even though the suppliers believes that it is 6 out of 15000 (Makotore 2002, pp54). Farmers here are reported to continue using the hose and the malfunctioning sprinkler because of the high replacement cost although some are simply buying and using garden sprinklers as substitutes or even furrow irrigation (*ibid*, pp82, 84, 121, 133). Users in traditional gravity schemes in Nyanga- Matema potato area and the Honde valley coffee and banana growers may have asked the same question.

Table 8.7.3 Classification of Christiansen's uniformity (CU) Values

CU (%)	Class	Percentage of data in class (%)
≥85	Very Good	0.00
80-85	Good	0.00
70-80	Fair	16.67
≤70%	Poor	83.33
Source: Watermeyer J.M 1990		

The wind speed recorded as shown in table 8.7.2 are generally higher than design wind speeds. This suggests that there is need to monitor wind at Mpudzi in order to get more representative data. The uniformity coefficients obtained of 40 to 77 percent rate as fair to poor according to Watermeyer's classification as shown in table 8.7.3 (Mugusto 1999). According to Wilson the 3 to 3.5 mm nozzle sprinkler operates in the range from 240 to 300 kPa. Under 12x12 m spacing it should attain good and fair distribution under moderate winds that is 8 to 16 km/h (Wilson 1974, pp9, Pilditch 1977, pp7). Therefore the performance obtained at Mpudzi is below expectation. The numerous leakages are also contributing to reduction in actual discharge. The net result is poor calculated application efficiencies of the system ranging from 53 to 68 percent as shown in table 8.7.4 (based on Keller and Bliesner 1990, pp 108-112).

Table 8.7.4 Sample calculated application efficiencies for Mpudzi upper block

Parameter	Design Sprinkler	Practice Largest Sprinkler	Practice Smallest sprinkler	Practice Average Sprinkler
Pressure (kPa)	350	250	250	231
Nozzle Diameter (mm)	3	4.55	2.5	3.7
Coarseness Index (CI)	21.64	9.21	16.77	10.22
Spray Type (fine if CI is 17 or more)	Fine	Coarse	Coarse	Coarse
Wind Speed Used (km h^{-1})*	7.92	10	9	7
Evapotransipiration, ET (mm day^{-1})**	6.62	6.68	6.68	6.62
Effective Portion of Applied Water ***	0.92	0.96	0.92	0.96
Christiansen's uniformity coefficients, CU (%)****	78	68	77.5	92.6
Classical Distribution Efficiency (%)	73.88	62.01	73.29	55.60
Application efficiency (%)*****	68.29	59.59	67.51	53.40

*Not clear whether to use maximum or average so calculations based on range of wind speeds. ** Using ET as per general design for capacity. *** Assume no leakages in the system i.e. total system discharge is equal to sprinkler orifice discharge. ****Using a desired adequacy of 80% although silent in design manual and design report. CU for practice based on field measurements. ***** All calculations based on 12x12 spacing of draghose systems **(Based on Keller and Bleisner pp 108-112 and field observation data: Mugusto 1999).**

This is lower than the design efficiency of 75 percent (Mpudzi FR 1993 section 11.2). Unfortunately the design efficiency used does not specify the desired adequacy and uniformity required. This makes it difficult for a realistic performance assessment to be made.

Lower Mpudzi block water delivery and equipment performance

Farmers in the lower block do not crop as intensively as the upper block. There is evidence of some plots that have hardly been cropped for two seasons in succession since the Block was commissioned in 1996. Some plots have never been used to grow a successfully marketed crop. The water delivery is reliable and secure. Most of the sprinklers and hose units are still in perfect working condition. One farmer in the lower block remarked that for most of them the only input they provide adequately to their crops is water. A fact supported by farmers who could harvest a plot with a wheat crop having one grain per plant. During operation a clear misting and wind drift is visible on most days. Only five good and enterprising farmers like Mr. Mah in the lower block had replaced hoses but not sprinklers by year 2000. They rely on heavy addition of manure and inorganic fertilisers. Most of the pressure regulators “scuds” are still intact and functioning well. Pieces of ¾ inch hose have been generally used to replace damaged “scuds” in this block.

Performance clouds on the horizon

As explained earlier, each individual hose sprinkler unit was designed with its own “scud” in order to regulate the amount of water that each unit should take from the system, to ensure that each farmer always has the same pressure. Originally, there was no analysis or even an attempt to understand the effect of the malfunction of any system component on the system distribution of water as designed, such as non-replacement of a scud.

A lack of replacement of hoses leads to leakages, which also reduces pressure in the system and directly causes poor water distribution. Abandoning the scud in favour of large hoses and sprinklers means that some upstream plotholders might never build sufficient pressure to effect good distribution.[29]. The absence of pressure regulators implies that downstream plots can now draw more water and over-irrigate or even leach their soils. Downstream irrigators could use the system at their convenience while the top users can only irrigate satisfactorily if the downstream users voluntarily co-operate in reducing their total and individual outlet draw off by using less sprinklers, smaller hoses and shorter periods. This has not been seen much so far, but the problems are coming in parts of the Upper Block in particular. (The Lower Block has less intensive use, and irrigators still keep their 'scuds'). Upstream irrigators will eventually increasingly become disadvantaged in Mpudzi due to hydraulic behaviour of piped gravity systems that tend to give more pressure and discharge to the tail end and open systems allow head-enders to draw more than tail users. This reduces uniformity of the system in either case (Keller and Bliesner 1990).

Currently the cooperation that exists in the upper block has contained the problem as farmers form upstream and downstream hydraulic groups who irrigate on alternate days during shortages to ensuring that all farmers get sufficient pressure. If this cooperation and stops for whatever reason or the system deteriorates further then the distribution of pressure among the farmers can become unmanageable as observed in Chakowa.

8.8 LEVERAGE AT MPUDZI

Re-setting draghose performance analysis

The uniformity of application is probably the biggest benefit that can be derived from modern piped and pressurised systems. By not paying particular attention to the uniformity the essentials of the pressurised systems are passed by. Unfortunately the Mpudzi system is not performing at its optimum uniformity. The process of addressing this issue requires a clear understanding of the system components and their relative contributions to uniformity. The individual pressure regulators at Mpudzi actually call for a further reduction of the field uniformity by 5 percent (Keller and Bleisner 1990). Regulators are responsible for increasing the anticipated uniformity requirement. The first leverage lies in recognising the need to

[29] This is due to the fact that hydraulic pressure is highest at lower elevations in a closed pipe system and this leads to higher outlet discharges in these locations. In closed pipe systems the discharge increases with pressure. The hydraulic relationship is given as $q=kp^{0.5}$. When pressure varies the discharge varies by a power of half.

balance the skills available, the level of industrial support available to match the requirements of the chosen technology.

Unfortunately the farmers and extension staff cannot undertake the level of monitoring achieved in this study. What is even more important is finding the possible ways of rectifying these problems so as to achieve higher system performance. Farmers are already contributing to low pressure and nozzle change by use of bigger hoses and bigger nozzle sprinklers in order to obviate night irrigation and wind effects.

Institutional-technical capacity

The technology only requires users to co-operate in the abstraction and delivery line cleaning and repairs. After that it is individualised. The very design advantage that was cited in choosing the system seems to be source of the basic institutional-technical capacity problem in the Mpudzi scheme. The farmers in the lower hydraulic locations in the block have no inherent benefit or tangible sanction for maintaining the system as designed except reduced leaching or waterlogging. This facility is peculiar to gravity systems especially if there is no facility for volumetric charging for use. The other draghose systems tend to have enforced co-operation due to the electricity payment requirement. This need is not evident in the drag-hose system like Mpudzi. The meetings and negotiations at Mpudzi are similar to those observed at Chakowa and Deure. They relate to sharing scarcity with equity as discussed in section 8.5. These primary level meetings result in the upper block farmers creating hydraulic units and irrigating on alternate days.

The system is meant to allow for individual operation and maintenance of infield works, but any O&M here does not affect the overall delivery capacity. Its effect is on the distribution performance - that was cited in making the choice especially between semi-portable and draghose. As outline, this has future implications for upstream farmers.

Without any mechanism of management support the infrastructure alone will never provide relief to the upstream farmers. There is no way of forcing the semi-demand system to build pressure without a mechanism of forcing the downstream demand to restrict its uptake of water.

Meetings to discuss secondary issues like distribution uniformity are far too complex and obscure for the farmers to deliberate on without expert guidance. The solutions are also not clear and again require good expert study and advice. This suggests that the modern technology design cannot be assumed to sustain itself without skilled personnel support. This is in keeping with earlier realisation made by Horst (1990, 1998). The in-built management that is said to be part of draghose, only exists if the right level of technical support provides services on a sustained basis. It is argued here that the second leverage lies in realizing that the local farmers and EW on their own cannot rectify the problems and achieve the objectives of using modern systems at Mpudzi.

Maintenance

The chapter shows that farmers in Mpudzi upper block are highly productive. They use the reliable water delivery continuously to distribute and apply water using the overhead system. Excessive wear is recorded for the hoses, hose-clips, pressure regulators and sprinklers. Farmers individually repair hoses mainly by tying up leaks with rubber. Replacement hoses bought are generally of bigger diameter than the designed hose. Pressure regulators are not used with the bigger diameter hoses. Bigger sprinklers are also bought in. The general nozzle diameter therefore increases from the design 3 mm to 3.7 mm. This leads to higher discharges per hose sprinkler unit. However the number of working hose –sprinkler units per farmer is found to decrease from the design 6 to 4. The technical performance of the system as measured by the uniformity is found to be lower than anticipated. The main causes are the maintenance regime and wind effects. A lack of institutional support to guide the users in effecting maintenance of the sophisticated system seems to be a dominant factor. The third leverage comes from the accepting that individualised operation of the system does not necessarily work well with individualised maintenance of the system components.

8.9 CONCLUSION

This chapter has shown that an overhead subsystem coupled to a run-of-river delivery subsystem has characteristics that include more than the effect of reliable water supply for intensive production. Water supply tends to have minimum regulation and control. However, continuous operation of the system significantly increases wear and tear raising the maintenance need. The users take their own initiative in coping with the high maintenance need in much the same way as run-of-river surface schemes. This is the point were the system high skill requirements in maintenance labour, specific and specialised equipment requirement become a major bottleneck. Diagnosis of maintenance needs and actual execution requires resources that are not local to the system. The technical performance of the system as measured in the upper block is much lower than anticipated.

One issue that came out very clear at Mpudzi relates to monitoring of system performance. Farmers in this scheme clearly showed that they are not interested in gathering or supporting the gathering of data that may be used by policy makers to make decisions that may affect their autonomy. The upper block expressed this through drawing up a list of shortfalls in design and implementation, but later participated in gathering data. The lower block was not open and effectively blocked the acquisition of data.

Handover processes in Zimbabwe have never really defined the obligations of the government and farmers. This makes it impossible for government to monitor the performance of FMIS on a sustained basis. This is one reason why short sample studies have dominated the technology-management-performance-viability debate in Zimbabwe. There is no body of consistent data and information that is being deliberately gathered on schemes to inform the debate and help in policy formulation.

The control and regulation relations between farmers and authorities for a gravity scheme with sophisticated distribution and application components are the same as that of simpler systems. Farmers want minimum interference from the state unless they identify a clear purpose for that intervention. The lack of physical structures like dams to regulate flow and avert floods or water shortages on the river supplying the scheme has created a situation similar to that in Mutambara discussed by Manzungu (1999). Farmers at Mpudzi will not find reason to participate in further water management programs unless it enhances their water delivery security. Irrigation scheduling for run-of-river water systems has no apparent logic as any savings are lost from the system. Therefore any attention to improve water management at Mpudzi has to focus on system water control if the farmers are to become meaningful participants. The current system cannot be made to perform any better than it is as long as the concept of farmer management is not fully embraced.

By deliberately sourcing such information on operational data collection problems in the management of schemes, this study makes it clear that such responsibilities cannot simply be handed over like the electricity costs and cleaning of canals. Farmers will make it impossible for data to be acquired if they feel it is not in there interest. There is need to revisit the handover process to define responsibilities that require central control or authority to be retained. The right to demand certain information from the users will be one of them - and will also require much negotiation.

The lower block at Mpudzi has all the requirements of a modern technology in addition to a reliable water supply with no institutional problems. However, the system simply cannot be productive because of the land capability. In Zimbabwe there used to be irrigation capability classifications by CONEX. Current planners have disregarded these classifications as evidenced by all the new feasibility studies that seem to basically offer two technological options only. These irrigability classes need to be revisited and incorporated into the discourse of technology choice, operation and maintenance. Otherwise, one is simply finding new technical options without reference to income generation, that actually burden irrigators with O & M problematics.

10 DISCUSSIONS AND CONCLUSIONS

10.1 INTRODUCTION

This comparative study has examined the technological trajectory and engineering precepts that have driven smallholder irrigation design. The technological and institutional preferences behind these have left gaps and weaknesses in both technology choice and technology care which farmers and local operators struggle to meet.

Scheer (1996), in a study of irrigation development in Senegal, felt that engineers are actually paid to follow the directions set by planners who drive infrastructure development. Planners have a *habitus* that

> "*ensures its own constancy and its defence against change through the selection it makes within new information or rejecting information capable of calling into question its accumulated information, if exposed to it accidentally or by force and especially by avoiding exposure to such information"* (Bourdieu, 1991 in Scheer, 1996, pp170)

As these have inconsistencies or follow existing or new paradigms, so too can the engineers they influence avoid self-criticism and field realities. They can thus stay with design preferences or prefer new choices that are consistent with these wider policies and plans (and the inconsistencies and gaps in them). Engineers can then avoid the questioning of a learning culture informed by transparent monitoring, evaluation and learning loops between farmers, designers, planners and policy makes. This final chapter reviews what might change in design choices and learning culture in smallholder irrigation development in Zimbabwe. It first summarises issues left by historical policy and technology changes. It then reviews the theoretical and methodological framework to see how better conceptual and empirical study can help engineering. It them makes recommendations for the future, building on both the farmers responses discussed in Chapter Nine, and an examination of ongoing pressures on engineers in Zimbabwe.

10.2 REVISITING TECHNOLOGY AND MANAGEMENT WITHIN THE WIDER PLANNING CONTEXT

Institutions, planning and authority

The policies that have guided smallholder irrigation development and management in Zimbabwe started with the duality of commercial against livelihood farming that was formally adopted by the regimes prior to independence in 1980. Two predominant paradigms dominated the socio-economic and technological arenas. The smallholder farmers were considered as vulnerable communities that required central and local government authority to ensure that they received and shared water deliveries equitably. They were also provided with cropping programmes and legally supported by-laws that guided their daily activities. Powerful irrigation managers were deployed to the schemes to ensure sustainability of water deliveries, enforce by-laws and resolve conflicts with full authority from the local government structures. Central to this management approach was the notion that continued residence at a scheme was dependent on faithful compliance with the regulations and controls set by the local government authorities and enforced by the local irrigation managers. Non- compliance could lead to eviction.

After independence socio-economic issues were immediately revisited as part of the empowerment processes of unlocking community innovation. This gave rise to the formation of IMCs that have dominated and have practically remained the cardinal point of smallholder schemes farmer organisation since then. However this persistence has not been accompanied by any serious institutional conceptual grounding since the pioneering work of one local irrigation expert in a local government department of DERUDE. This gave rise to a Draft Smallholder Irrigation Policy[1]. IMCs have therefore been assumed to possess abilities to create and utilise technical and managerial capacities that in reality are alien to the members. This culminated in unsuccessful attempts to even expect some IMCs to incorporate as companies. The capacity assumptions were also central to the adoption of modernised water control systems that took place in the early 1990s.

Less systematically acknowledged however was the impact of financial reform paradigms, and the politics of bureaucratic reform, through which planners and senior bureaucrats dictated change without clarity on local competences. The most important was the radical decision to shift all pumping costs from government institutions to the 'beneficiary' farmers. This was informed by an assumption that smallholder schemes developed in all parts of the country could, through proper training and extension support, be induced to grow high value crops that enable them to meet O&M cost requirements. Due to its direct effect on water delivery supply, farmers through IMCs have taken up operational costs with varying levels of success and sustainability. In general high pumping costs have eroded the wealth creation capacity of most schemes and left the farmers vulnerable to energy cost increases.

Also less acknowledged has been the gradual demarcation of engineers into design work only, with senior and director-level staff becoming part of a technocracy – planning and governance by technical experts – who have put their own interests and paradigms into irrigation planning and design. Thus the preferences of these planners have become divorced from the insights of engineers who put systems into practical use.

In the process of shifting responsibilities to farmers, an innovative design provided for the divisibility of maintenance costs to individual farmers at plot level in pressurised systems. This was however not synchronised with similar partitioning capacities at higher system or upstream levels as well as at operational level or field levels. There are no matching demand based schedules to enable individual operation and no charging reflecting individual use of water. Similarly institutional facilities to monitor and enforce maintenance at all system levels were not attended to, resulting in neglect of maintenance particularly at individual plot level. The ripple effect of this has not been quantified due to lack of monitoring and evaluation of delivery performance. Farmers have not met the maintenance needs and requirements of the sophisticated systems, and solutions are being sought to rectify the problem on an individual scheme basis. There is no defined national policy position on ownership structures for smallholder irrigation assets. This continues to cloud attempts to clearly define transparent and sustainable institutional structures and financial accounting procedures that can satisfy <u>all</u> stakeholders.

While fees and maintenance charges have never been revisited, nevertheless planners have reformed the direction and flow of funds, into arcane suspense accounts that IMCs know little about and do not understand. The rhetoric of private sector action has driven farmers onto the private market for loans and repairs, where they may risk their assets. IMCs lack legal and state administrative support for achieving transparent financial and accounting procedures. Some people have even raised issues of the potential to create and utilise such capacity, without consideration of providing appropriate incentives to the local leadership to ensure sustainability. The question of ownership and streamlining responsibility has been nicely avoided to date in spite of its vital importance to sustained asset management. This has

[1] Meinzen-Dick says this was the only comprehensive piece of work that ever attempted forming an irrigation policy in Zimbabwe (Meinzen-Dick in Rukuni 1996).

fuelled and sustained the current paradigms of technological fixes that are in the main driven by central government planners.

Extension support at the schemes is weak in demand management due to an absence of an irrigation culture, and has also been undermined by lack of clear plans and funding. There are no scientific attempts to manage water demand at scheme level due to training and capacity creation and utilisation constraints (Nijman 1993). The institution that is largely recognised as managing the schemes completely or jointly with government is the IMC that has become a requirement at all schemes.

IMCs have done well in appropriating simple operational and maintenance requirements. However they have failed to take care of maintenance and replacement requirements for components that require skills outside the village capacity. They are also weak at mobilising and accounting for maintenance-related financing. However they have proved superior in mobilising operation costs like electricity and distributing income among peers as shown in tomato payments. This has led to situations where the performance of sophisticated water control systems is lower or in the same range as simple technology systems. Farmers and local government workers act in many dimensions to leverage their water supply.

This study shows that an option of high value crops seems more related to the market than to the water delivery. The farmers practices in Chakowa, Mutema and Bonde show that they are more concerned with secure production on a unit of cropped land than spreading water over bigger areas with less secure water as found in Mexico (Kloezen 2002). This is in contrast with the planners calculations based on normative efficiency values (Savva 2001).

From surface simplicity, low cost and divisibility to sophistication, high cost and individual control

The technical paradigm that persisted until the early 1990s was that surface irrigation was the best system for simple smallholder farmers due to its matching simplicity and flexibility. Initially, schemes were small, and evolved with new blocks added over time. It appeared that irrigation managers as much as designers decided whether sufficient water was available. Where blocks were dropped, it appears this was done both at the design stage and also after struggling with poor delivery. Depending on geography and history, either strong manpower controls managed cross-block equity (as at Deure) or night storage dams with control were built often at locations where it was assumed management could control and prevent water theft. The relative options in technical and managerial control of cross-block equity have never been revisited.

Surface systems, especially those with NSDs were known to have bilharzia risks. This was addressed through additional programmes of mollusciding. Later attempts were made to design both canal artefacts and operating routines to prevent snail build up[2].

Since the 1970's some technocrats even listed superiority of surface systems with respect to water use efficiency and distribution uniformity. However, it is at this point that we see a shift from thinking about production from systems, or production performance, to focusing on technical criteria of water delivery performance, at the same time losing understanding of how people and not only artefacts, act in water control.

Engineering precepts, rather than being shaped by commitments to robustness, water security and production security, became more directed at notions of individual water control and reduced management need, reflecting wider rhetoric of privatisation and commercial cropping. This helped drive the experiments into overhead systems. The problems of

[2] Stilling basins were eliminated, NSDs were discouraged and irrigation schedules to allow for alternate and maximum drying periods were provided to control snail population build-up (Chimbari et al 1991).

supplying water to less favoured areas (with more distance from rivers, and poorer soils) came up, but this became treated as a scientific challenge without too much thought about practical management especially while the state seemed so prepared to keep paying costs for smallholders. Here the precepts got involved in a sense that irrigation potential must be mobilised and can technically be mobilised – without thinking of what was viable in operations and maintenance under a changing state economy, This led to the pumped schemes like Mutema, and the grand Bonde, whose farmers had to pay a fortune in costs while watching their neighbours at Deure run their gravity systems for very low costs.

Generally the technocrats agreed that the cost of lifting water for enhanced water control by pressurised distribution and sprinkler application could not be a justified cost item for the government. However, initially it was also recognised that the costs could also not be passed on to the smallholder farmer on a sustained basis. However, even this recognition was dropped. This was partly from exposure to the rhetoric of privatisation and practicalities of financial reforms in the government. It also followed assumptions that farmers would both grow high value crops automatically with more sophisticated technology and get profits sufficient to pay spiralling costs (now with incentives and advocates for payments in foreign exchange), and would continue to use electricity. However, they have still not agreed on responsibilities. Diverse arrangements remain between pumped schemes on whether government is involved or not and to what extent.

In chapter 1, I referred to the problem fields that Leeuwis identified to which innovation is often expected to respond – that is changes in the social environment, perceptions of reality, human aspirations, social and technical opportunities, and natural/physical circumstances. However, these reflect more the fields in which local actors have provided leverage to support change. Zimbabwean irrigation designers have not approached these systematically but have rather followed the directives of planners and technocrats.

10.3 THEORETICAL FRAMEWORK AND METHODOLOGY

This thesis has struggled with four inter-related domains of research, to show:

i) the problematic of smallholder irrigation in Zimbabwe
ii) the relations between irrigation infrastructure and management
iii) water delivery performance in relation to people's actions and not just technical performance
iv) how to improve learning that brings relevant design of systems and their operation and maintenance.

The complexity of smallholder irrigation is mainly attributed to "multiple proprietorship" that characterises the scheme decision-making processes in an environment of generally low incomes that make most schemes "livelihood enterprises". Where net incomes are sufficiently high, smallholder schemes tend to join the mainstream commercial agriculture dominated by individualism. Where incomes are so low that the net plot or individual income is only a small nutrition component or supplement, the enterprise is generally considered a social activity and central governments, local authorities, donors and any form of assistance tends to provide financial assistance on a grant supply basis. Requirements for institutional organisation and appropriate technological interventions are then determined without the recipients or - if they are consulted - their veto power is not of substance.

Between these two polar points lies the problematic, smallholder schemes mainly found in Zimbabwe and most of central Africa. The problematic is compounded in this region by:

⇒ a short irrigation history,
⇒ aridity and water insecurity that places water mobilisation outside the financial and technical capacity of the farmer groups,
⇒ low value "livelihood" crops grown and the subsequent low income levels of the farmers and lastly
⇒ the need to stretch the water resources to maximise benefits.

The cropping patterns summarised by Rukuni in 1984 have been found to persist in smallholder schemes in Manicaland despite all documentation alluding to change from livelihood to high value crops. New dimensions that had been added and flagged - calling for a revisit of institutional issues - have essentially been shelved after the Derude draft report. In this respect, the schematic issue-based models of Moris (1987) and Tiffen (1987) developed from their field surveys, and summarised in Chapter 1, still apply. These then are still core issues for any feasibility and design study. Central policies have shifted from control of smallholders for a particular role in development to rather loose assumptions about how irrigation can change production without thinking about necessary support or control.

The study tried to find a framework to study the management of irrigation technology in reality, but looking at the management support subsystem (MSSS) in place to operate and maintain the various water supply sub-systems studied in this thesis. It was found helpful to look at the MSSS in terms of three fields - its regulation and institutional control mechanisms, the actors and resources in operations and maintenance, but also at the monitoring and evaluation used (or not) in transforming designs and management practices. The study tried to look at these procedures in reality, and to see where farmers and other local actors had to apply additional leverage to get their water supply.

What appeared was a design process strongly shaped by planners' preferences, both on the forms of control they wanted to superimpose, but also on the narrow technical performance criteria they used either to justify more sophisticated technology choices, or to highlight that farmer-managed systems performed better than agency-managed systems. No real monitoring was done of field-level realities. When the actions of leverage within the system environment were investigated, farmers concerns put very different preferences into view – for water delivery security, to design what can be maintained, to question and pressure for ownership structures and get better regulation and control. Thus the model was a useful one, but had to be backed up by field research showing local practices and not only the scientific measurement of water flow.

Operational practices on the ground were analysed using the socio-technical framework and actor-oriented approaches (Manzungu 1999, Vijfhuizen 1998, Magadlela 1999). These helped to trace the activities of a few key individuals such as water bailiffs and water controllers. The method was not adequate for use with professionals and other key influential planners. These were analysed using the soft systems methodologies that allowed their worldviews to be reduced to analytical components. As pointed out by some, there was always the danger of objectifying or "reification" of the models created in the analytical processes into realities, (see Manzungu 1999 pp 158, Nijman 1993, 228-229, Sheer 1996, pp213 box 17.1).

Methodologies used in the performance study included informal interviews, observation of field irrigation and maintenance practices, measurement programs for water deliveries and calculation of performance indicators as detailed in chapter 1. This measurement also linked in the performance study. Quantification was easily done using the standard performance determinants (Makadho 1994, Molden *et al* 1998). In this respect, this study has also extended the technical horizon of applicability of Makadho's findings (Makadho 1994) on reliability and water delivery performance from surface schemes, to sprinkler schemes and a variety of technical combinations.

Water bailiffs measured flow at government managed irrigation schemes (GMIS). Farmer representatives or farmer employees collected flow data at FMIS. The collection of data by farmers proved problematic raising questions on the feasibility of increasing water use efficiency on FMIS without government regulation and control structures. There is a gap in the perception and need for water use efficiency that created methodological problems. Farmers regard flow data with suspicion as they generally thought it was meant to introduce volumetric charging as detailed in chapter 8. There were calls to engage staff to capture flow data at FMIS. The close proximity between GMIS and FMIS at Deure and Bonde made this decision process particularly difficult[3]. The study was restricted to water delivery measurements only and this limited the range of indicators that can be determined. Productivity indicators as summarised by IWMI and timeliness indicators that Makadho determined were not calculated due to scarcity of data and time (Molden et al 1998, Makadho pp53-55 in Rukuni *et al* 1994).

Studying schemes with endemic problems like Mutema, Lower Chakowa, Lower Mpudzi and Bonde proved particularly difficult but quite informing. The farmers succeeded somewhat in directing research efforts to cast more attention on their problems. This may have been an attempt to get their problematic covered. Unfortunately they invariably used the tactic of not co-operating thereby leaving the analysis sometimes quite qualitative. Therefore both consultative and diagnostic approaches were used to inform the outcome of this study in line with Keller's recommendation (Keller in Sampath 1990, Kloezen 2002, pp21), the latter being used more in problem contexts where farmers participated less in consultations.

Like van Halsema (2000), this study also found that

> "*…in the elaboration of O&M procedures, too much focus went on the technical management requirements (for the system). There has hardly been any scope and attention for the processes of management in terms of institutionalising the control mechanisms and allocation, scheduling and distribution within the management practices and domains of irrigation departments and water*" (van Halsema pp. 291-292).

The identification of suitable performance indicators that can reflect the reality on the ground is still difficult. I agree with Kloezen that comparative indicators as given in appendix 1 are good for giving a broad picture of the reality on different schemes. Relative water delivery figures can lack value connotation in that it they also act as internal process indicators (Molden 1998, Kloezen 2002, pp 235). I found RIS more satisfactory than RWS because of the rainfall contribution, especially for the Mpudzi scheme that lies in a higher rainfall area than the other schemes. However I resisted the temptation that I have observed elsewhere of expressing the RIS over a year or a whole season because this reduces the quality of interpretation of the indicator especially for crops with critical demand periods like maize. The RIS of maize - the livelihood crop for Zimbabwe - gives the maximum information if it reflects the quality of delivery during the most critical period of the crop (Doorenbos and Kassam 1982). Farmers' decisions and actions are also informed by the way

[3] A decision to pay for data collection at Bonde would have raised questions at Deure. Paying for data collection at only these two schemes would have signalled the wrong message to all other schemes. The final collection of data by only paid individuals would have meant that I as then head of irrigation would have accepted that the process of data collection is separate from the ordinary responsibilities of those resident at schemes. Thus the concept of plot level demand management would have been given an additional need to create capacity before attempts at utilisation. From my experience and from this study I am convinced that farmers with necessary academic qualifications can be relied on to capture data at their schemes or plots provided they receive necessary support and guidance. To discard their data means that we are back to reliance on big commercial farms as a testing ground for any agricultural innovations. It also shows the endemic irrigation professionals' mistrust of smallholders as development partners and heralds problems for IMT unless there is a mind shift.

the supply and demand vary during this period. The whole policy of irrigation for livelihood purposes in arid regions of southern Africa revolves around this critical period. Therefore it is crucial that the indicator should amplify the water delivery performance at this time as shown in this study.

One of the most difficult methodological problems was the study of practices in one's own working environment as discussed in chapter 1. When I started I had noticed a phrase from Cees Leeuwis that warns of the dangers for SSM users of the baby being thrown out with the bathwater (Leeuwis 1991). I am not sure if this didn't happen to me. The practicality of studying from within produces very interesting revelations for a learning situation. However it can also have very real implications for the researcher's welfare both during and after the study. I am proud though of the new culture of questioning that seems to be running through the irrigation fraternity.

Informal interviews and observation of field and maintenance practices focussing on the six schemes gave insights on problems in design, albeit with a case study bias. This however provided an opportunity to get a thorough contextual understanding of the interactions of design, operation and maintenance. The role of planners only became clear during second level analysis of the research findings and more detailed study of similar works elsewhere. The pioneering work of Sheer in Senegal provided useful insights as it shed light on communication gaps between farmers and engineers that had been observed in the field but apparently lacked meaning (Scheer 1996). The study of maintenance practices and their effects on operation proved to be particularly difficult as they are not easy to isolate, control or identify direct cause-effect relationships within a short time. They also call for considerable understanding and experience in design, implementation, and institutional issues. This sometimes tended to cast a fair amount of abstract thinking processes in the study leading to loss of communication with clients or those that would be change implementers. While Checkland warns of such dangers in using the SSM the shock of experiencing the communication breakdown still remains (Checkland et al 1990).

Design issues required a process-based analytical framework because it is not possible to attribute all outcomes to individual actions. Management conditions and control need to be considered. Nijman's adaptation of the concept of levels of sophistication was used[4]. Besides the problems of using questionnaires in the field the concept also presents serious communication problems. What I now hope for is that this text, and the simpler schematic models used, can help aim at new reflection and a new process of consultation without too much abstract language.

The method however enabled an essential separation between planning and design that is problematic with SSM. This was particularly useful in finally mapping some of the current sources of paradigms. It was also important in mapping the way forward in draghose systems as it enabled a separation between the need for technical water control capacity creation and capacity utilisation that Manzungu had earlier found as a common limitation (Manzungu 1999, pp80).

However besides the identification of the gaps, processes and actors the earlier approaches (mainly SSM and actor-orientated) failed to explain what informed the decision processes that farmers, designers, politicians and other involved players use. It failed to explain their coping strategies. The leverage approach provided some insights into how the different individuals and institutions strategize. It also provided some ideas for mapping the way forward.

[4] Nijman says he used an earlier adaptation by Marcelis (Nijman 1993, pp30).

10.4 RECOMMENDATIONS FOR THE FUTURE

Irrigation design and development in Zimbabwe needs to rethink its engineering precepts and its technological trajectory. As van Halsema (2002 put it

> *"….The issue at hand is that of purpose and functionality. Can… (they)…be predetermined and purposefully designed and developed, as lies at the centre of engineering…or is this simply a matter of (evolutionary) chance. To meet the conditions, there should first be an accommodation and consensus of what the desired purpose and function should be…this is not a simple matter of problem analysis and optimisation. It involves the complex matter of reaching consent on the strategies, objectives and purposes that users and operators are willing and capable of pursuing in water management."* (Van Halsema, 2002, pp.290)

In this final section, I try to bring a wider agency perspective into future needs and accommodations, although these are complementary to the gaps already identified local leverage to get water security, designs that can be maintained, clear ownership and better regulation and control around systems.

Be realistic about farmer management and joint management

Experiences elsewhere have pointed out that this farmer management is only applicable to simpler technologies, or is developed for more sophisticated equipment through earlier experiences. In this study the simple stabilised water delivery at Deure is managed well, although drainage and support structures are neglected or assumed to be the sole responsibility of the government except in Block A. In communities with a strong traditional social organisation it has also been possible to manage new technologies or to grow the capacity to manage such systems (Matsika in Manzungu 1996).

In this study Musikavanhu farmers are seen to have made a remarkably good start in coping with only operational aspects of the borehole water delivery system. However other sophisticated systems have experienced clear gaps in terotechnology as highlighted in chapter 5, 6,7 and 8. It is proposed that the two approaches of service provision by private organisations and asset management by quasi-government institutions be considered simultaneously. An appropriate choice can then be made for each system configuration and phased in to address the yawning gap.

These shared resource management structures need to "*combine the triple competence of design-implementation-operation*" in order to "*pace their investments to the water demand, paying good attention to the oncoming recurrent operating costs*". Tardieu and Plantey recommend that investments and operating costs of public hydraulic asset management institutions compare with other facilities. These utility institutions should be answerable to all members to ensure financial transparency and accountability that determines the growth and sustainability of the organisation or institution (Tardieu and Plantey 1999).

There is a need to match increases in farmers' capacity to utilise new technologies with technological innovations designed to tap the new level of demand. Ideally this should gradually result in a transformation from supply to demand water delivery schedules. This should ideally be accompanied by a gradual development from simple combinations of operation and maintenance in farmer management, to a service provision split between water allocation and scheduling, and asset management for maintenance of the water delivery artefacts.

It is recommended that a shift be made from the current top-down, supply-driven, field-focused water control based on narrow technical approaches only. There is need to adopt a holistic system based approach that starts by first improving farmer-based water demand. This calls for improving farmers' capacity to anticipate and progressively monitor their water use so that they become meaningful partners in water resources planning or consultation processes. This is in line with the WRMS (2003) document to develop a water resources management strategy, towards integrated water resources management, improving stakeholder participation (see also Pazvakavamba, 2000). There is also a need to provide appropriate manipulation and management of "shared or water mobilisation and delivery" assets on the basis of long-term continuity, transparency and public accountability. Thirdly there is need to ensure provision of adequate, relevant and sufficient regulatory and control structures founded on sound legal provisions to safeguard public interests in a environment that is sensitive to professional, effective, efficient and economic excellence in discharge of duty.

Work to build new service options

Mupawose states that irrigation development can be a vehicle for facilitating development of an irrigation-based industry (Mupawose, pp iii in Blackie 1984). This basically looks at the opportunities that can be opened up to service both simple and sophisticated irrigation water delivery systems. A case in point is gate-making by Metfab in Bulawayo since the launch of such structures by Ball (Manzungu 1999, pp 118, 130-131). The adoption of more sophisticated water control methods requires more support from the private sector than simple technologies. Incentives at both plot and shared asset level like ISO certification and competitions also need to be encouraged (Tardieu and Plantey 1999 pp 3-4).

For example at Mpudzi the farmers have to buy spares in Mutare from different suppliers who in a lot of cases are just hardware outlets. Specific performance attributes of the WDSS system require field attention from technical agents to assist in nozzle sizing, pressure measurements and system evaluation. This service cannot be sustainably provided by direct government institutions like Agritex. There is need to plan the service requirements and guide both the industry and farmers into a mutual relationship that is required for the draghose systems to give and retain optimum performance at least cost. The Zimbabwean smallholder farmer and even the local Agritex office is not equipped enough to monitor and evaluate, repair and service sprinklers as required as observed at Mpudzi. There is scope for entrepreneurs to service this niche.

There are lots of other opportunities for service providers to take over functions that government is presently undertaking or attempting to hand over to farmers. The only requirement is that the service provider is able to show the investor that there is a profit is at the bottom-line. The Government could help this and provide the necessary information as well as remove unnecessary competition or crowding out. One possible area that government may need to open out is the system planning and design[5].

The current proposal to split irrigation between two ministries so that research and management are separated from planning, design and maintenance is likely to reinforce the *habitus* of planners and designers who will no longer be directly exposed to questioning and analytical processes due to structural and institutional boundaries. They can therefore sustain any ideologies and paradigms that cross their minds. This will effectively protect them the analytical and questioning rigours of a learning culture informed by transparent monitoring, evaluation and learning loops for farmers, designers, planners and policy makers.

Thinking a new about asset management strategies

The options of farmer management and service provision are informed by two different organisational arrangements, between which there is still a wide gap. Farmer management for the average current smallholder farmer in Zimbabwe basically requires simple technologies

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[5] I know this will be unwelcome news to some irrigation branch members who wanted to maintain access to funding and retain the branch identity and superiority as the as the centre of smallholder planning and design while crowding out the private sector.

and is best done within traditional structures that can lose effectiveness and efficiency with increasing community size and heterogeneity. This simplicity has led to minimum development of modern concepts of ownership and financial dealings. To successfully adopt service provision options requires that farmer participation and ownership structures be clarified and enhanced. This provides entrepreneurs with opportunities to clearly identify opportunities for quantifying and charging for service directly to consumers. These charges could be set to taking into account terotechnology and aging of infrastructure that are additives to the profit and loss bottom-line analysis as depreciation costs. Government can then consider providing targeted subsidies to the vulnerable members of the community as well as directly subsidise or finance selected components of the public utility assets.

The analyses here of maintenance of infrastructure revealed that there are numerous instances where the ownership and financing in assets is not well defined. This situation may be resolved by trying to rigorously allocate each component to institutions or farmers. However experience in other sectors shows that this process creates problems of divisibility and viability that have led to the acceptance that certain assets should simply be classified as public goods. Their service cannot entirely be allocated to individuals on a profit basis as they have poor exclusion facilities. In smallholder schemes studied these properties clearly show up in drains, support infrastructure like roads and offices as well as support services like the poorly supplied clerical and accounting services. The retention of plant for hire to service smallholders in land levelling, drain and road maintenance has proved difficult to pass onto service providers. The volume of works at each site may be too small for each small scheme to hire periodic services and transport equipment over long distances[6]. Considering the importance of land levelling to surface irrigation as emphasised by Walker it is imperative that an institution be identified that can provide such a service to the smallholder with reasonable attention (Walker 1991, pp202)[7].

The provision of maintenance services to such assets as drains, roads and land levelling are some of the forgotten tasks that Agritex failed to address in the handover process. The state of this infrastructure is conspicuous at ground level and the poor quality of tero-technology is visible even to a passer-by. It is therefore proposed that an additional provision be allocated that will provide these services on a caretaker basis for those that have potential for entrepreneurs to take up. Non-viable but essential services require that where feasible and appropriate the farmers can be train to take-over as a local institution. Where none of these conditions can be met in the long and short term basis, the retention of a service provision unit is advocated, with the adoption of modern asset management approaches for management of public hydraulic utilities (Hofwegen 1999, Malano 1999, Hall 1999, Plantey 1999).

Particular attention needs to be paid to choosing an appropriate and transparent service delivery, billing and accounting system in order to justify and encourage maximum farmer financial contributions as well as pave the way for support from government and other external support institutions. At conception stage it was hoped that the SISP and ARF programs as discussed in chapter 2 would eventually dovetail into each other and form the foundation of such institutions[8].

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[6] Earthmovers at times simply request the client to pay for transport from and back to any current location of plant within the country. It is then not surprising that the transport cost alone may be more than the actual works to be done on the smallholder scheme.

[7] According to Walker *" Levelling or smoothing operations may be required nearly every cropping season where substantial cultivation disrupts the field surface. The preparation of the field surface for conveyance and distribution of irrigation water is as important to efficient surface irrigation as any other single management practice"* (Walker, pp202, 1991)

[8] Suitable interfaces with quasi government service providers like ZINWA, ZESA, Meteorological Services and DDF need to be worked out to avoid undue overlap and ensure that current grey areas

Centre on realistic plot-based demand management

Institutions like Agritex probably find the statement that farmer based demand management is still lacking surprising after early pioneering documentation provided by senior managers (Makadho 1990). However as Manzungu pointed out the farmer's plot level conditions have always been left to the local extension staff (Manzungu 1999, pp110). Any future attempts that do not address and focus on the extension worker's, plot level operations and maintenance contribution to sustained demand management will in Horst's expression "*remain cosmetic surgery*" (Horst 1998). Future system choices need to be based first on farmer preferences on technical improvements. Introduction of higher levels of water control need to be well planned and highly consultative, and where possible encompass growth processes likely to meet requirements for participation, empowerment and technology transfer. A full grasp of the farm economy and its social fundamentals need to be used in further "*crafting*" of institutions that will be involved in looking after shared resources (Ostrom 1992). This calls for an understanding of the capabilities and willingness informed by cultural norms and values of the community to undertake the hydraulic management tasks on a sustained basis.

The current improvement strategies have been aimed at creating management capacity and control through use of pressurised systems that have capacity to "package water" for the individual user. However, use of shared pump units impose sharing and subsequent supply conditions that militate against individual water control and scheduling, as observed in Musikavanhu and Bonde. These virtually produced co-operative type irrigation practice that has no capacity for individual scheduling or demand management. In this case the technological intervention failed to create capacity and conditions for plot level demand management. This lack of system capacity and conditions to control water is the most common limitation to plot level scheduling (Perreira 1996,1998). In this case the limitation to control is the lack of flexibility in the delivery system, that is the pump unit.

However in Zimbabwe advances have been made to remove the supply-based pump units by introducing gravity supply as in Mpudzi (and automated pumping units at Negomo and Ngezi). These systems have capacity to supply individual plots with a limited flow on demand and therefore management capacity and conditions were created. In practice however the management utilisation capacity at the scheme level was not created as discussed in chapter 8. It is possible for the extension staff and farmers to be allowed to "grow" with the technology by starting to record water deliveries to individual crops on a time basis (Shearer 1987). Once they appreciate and share the vision for relative irrigation supply (inverse of water use efficiency) improvement they can on their own request or even engage technologists to install measuring devices and thus increase sophistication as was witnessed in Spain (van Bentum 1993, Nijman 1993, pp233).

Build an appropriate policy and monitoring structure

An appropriate policy is required to rededicate, guide, regulate and control planners, designers and farmers, service providers and asset managers as appropriate in the process of building, implementing and managing this total agricultural hydraulic system[9]. A legal and state based financial audit system needs to be provided to monitor and control tendencies for

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like weirs, pump stations, conveyance canals and their service roads, conservation works and fences, drainage, control and regulation structures are suitably and adequately covered.

[9] For example Egypt has a policy that forbids surface irrigation on sandy soils in some New Lands areas to curb water logging and salinity. It also has laws that forbid charging for water (Cornish 1998, pp28, 34).

perpetuation of self interest as well as to foster, cement and guard public interest[10]. Adequate, transparent, user determined tariffs and management structures need to be elaborated on.

The current efforts being made by MRRWD and ZINWA need to be catalysed so as to incorporate smallholder users meaningfully, while adequate attention is placed on the uniqueness of their hydraulic demands. Allan typically characterised agricultural water demand as "high volume, low quality and low (un-) priced" (Allan 1998, pp 4). This is a particularly true and appropriate starting point for smallholder farmers in Zimbabwe as shown by performance of schemes like Bonde and Musikavanhu in this study. Use of low quality water at Mutema has however defied this generalisation.

The management capacity to control and utilise water require clear supporting and enabling policies that will safeguard investors, operators and water users alike at both plot and shared asset level. The traditional starting point in preparing a feasibility study by Agritex has been obtaining a water right. In the case of groundwater a statement on yield is considered sufficient. What has not been considered is that a water right or a water permit is simply a statistical probability statement. It is informed by hydrological calculations from the hydrology branch and or a ZINWA official and a feasible cropping program and water requirements from Agritex. At the moment, there is no obligation or attempt to operationalise the water allocation or revisit and revise it to match with actual scheme requirements on the part of the issuers. Individual farmers and managers of corporate institutions use the allocation to plan and justify investment into production of certain commodities.

A gap exists in the smallholder sector as nobody is charged with its performance monitoring and evaluation. The net result is that virtually no water rights or water permits have ever been reviewed based on system or production information. There is no monitoring of individual farmer water delivery, actual water use, production costs and incomes, maintenance and other investments, nor of the problems farmers face. Therefore there is no documented basis for scheme water delivery system improvement planning at individual plot, block and scheme level. The anticipated improvements are based on paradigms or assumed benefits that appear in international literature and are largely driven by planners at high level in government or technical support organisations (Scheer 1996, 170). There seems to be a general lack of appreciation of the leverage that a well researched, informed, realistic and practically oriented policy framework can provide in ensuring a sustained development of irrigation in Zimbabwe. Such a policy framework can also incorporate the terotechnology requirements.

Rethink engineering and design: the last word

The paradigms that are driving the heartland of the largely technical based interventions are found to be supply-driven and top-down developments championed by those in the highly placed "habitus" of public institutions (Bourdieu cited in Scheer 1996). These "planners" have come to cherish sophisticated water control and application systems, implement them at all costs with what Scheer calls "superficial" user and sometimes designer participation, and immediately put a hard stop to further meaningful dialogue (Scheer 1998 box 14.3 pp170, Zawe, 2000).

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[10] Underhill cites a lack of concern of some civil servants who accept projects because of the personal benefits in use of transport, fuel, equipment etc and not because of benefits to farmers (Underhill pp 15 in Blackie 1984). Tardieu and Plantey warn strongly that; " *The pre-eminence of the long term general public interest over the short term individual interests can never be taken for granted. This implies constant vigilance in the respect of a coherent policy on the part of local authority, once the collective solution has been adopted: the public service of water resource management cannot be dependent on the sole laws of the market, and the role of the state is essential in safeguarding the coherence of such policy"* (Tardieu and Plantey 1999, pp4)

Some interventions have therefore, to use Speelman words been "orphaned" at birth as they do not even have a "surrogate mother" when they start operating as evidenced by the Bonde pumps[11]. This essentially reconfirms Speelman, Moris and Tiffen's concerns about irrigation as a "*privileged solution*" not based on its effectiveness but on its continued access to scarce resources that are wasted due to lack of proper and adequate planning, design, implementation and management (Speelman 1990, Moris 1987, Tiffen 1990)[12]. The essential linkages of farm demand management, shared or public "asset" management, and supporting regulatory and control mechanisms with a legal and public legitimacy do not seem to exist or to have been seriously considered.

This essentially calls for an elaborate system of checking the balance between "*quantity and quality of decision making*". There is need to "*get the conditions and processes right*" as well as "*doing things right and doing the right things*" to guard against just "*throwing money*" to the "*privileged solution*" (Nijman 1993, pp233, Murray-Rust and Snellen 1993, Moris 1987). Also for irrigation professionals to focus on the under-performing schemes with the objective of improving them and in the process gain insights into how to increase the level of sophistication of their decision making processes (Nijman 1993, pp233)[13].

It is always difficult to determine where the planners reside and derive their power. Scheer concluded that they tend to be typically found in the "blind spot right in the middle of the professional heartland of design engineers" (Scheer 1996, pp223). This suggests that it is the practice and the art of designing that has elements that drive paradigms. Nijman suggests that the one way of addressing the issue is to continuously improve on the information and processing for decision making as is typical of learning institutions (Nijman 1993, Scheer 1996, Senge 1990).

Papanek (1997) described design as 'the conscious and intuitive effort to impose meaningful order'. For too long, designers in Zimbabwe have prioritised technical and institutional paradigms and justify their own order, which have no clear meaning to smallholder farmers. Engineers in Zimbabwe need to be people who understand and are interested in how irrigation systems are used, not only how to design and construct equipment and artefacts. They also need to have engineering precepts that contribute to robustness, sustainability and water security of systems for smallholder farmers, not just individualising water use.

[11] The Nenhowe pumps have had a similar situation as detailed by Bolding (Bolding in Manzungu *et al* 1996)

[12] Makotore says that some of the interventions border on wishful thinking (Makotore 2002.)

[13] A clear focus on training extension staff in irrigation engineering and agronomy as well as measures supporting industrial equipment supply growth and quality are required for adopting sophisticated technologies (Cornish 1998, pp 19, 34)

APPENDICES

Appendix 1.1 Three phases of progression for irrigated agriculture

Description	Phase I	Phase II	Phase III
Disciplinary Orientation	Civil Engineering	Agricultural Engineering	Systems Engineering
Challenge	Get water to fields	Make agriculture more productive	Raise total factor productivity
Maximize returns to-	Capital	Land	All factors
Factors Limiting Abundant:	Information Water	Land Labour	Water Information
Farmer Knowledge	Little	Growing	Considerable
Management Mode	Technical management by agency	Joint management- by agency & farmers	Devolved management by farmers

Source: Uphoff 1999,pp 35 in Proceedings of National Conference on participatory Irrigation Management, Govt. of India, Ministry of Water Resources.

Appendix 1.2 Indicators for Comparing Performance of Irrigated Agricultural Systems
(source: Molden et al 1998 MWI report no. 20 pp4-7, Kloezen 2002 pp248-249)

Relative Water Supply = $\frac{\text{Total water supply(Irrigation+Total Rainfall)}}{\text{Total crop demand at field level}}$

Where, Total water supply = surface diversions plus net groundwater draft plus rainfall.

Total crop demand = potential crop ET, or the ET under well watered conditions. When rice is considered, deep percolation and seepage losses are added to crop demand. The consumptive use calculation is standardised by using FAO's CROPWAT method.

Relative Irrigation Supply = $\frac{\text{Irrigation supply}}{\text{Irrigation demand}}$

Where, Irrigation supply = only the surface diversions and net groundwater draft for irrigation.
Irrigation demand = the crop ET less the effective rainfall.
Note: The relative irrigation supply is the inverse of the irrigation efficiency presented by Bos (1974). The term *relative irrigation supply* was presented to be consistent with the term relative water supply, and to avoid any confusing value judgements inherent in the word *efficiency*.

Water Delivery Capacity = $\frac{\text{Capacity to deliver at (sub) system head}}{\text{Peak consumptive demand}}$

Production Per Cropped Area (US\$/ha) = $\frac{\text{Standardised gross value of production}}{\text{Irrigated cropped area}}$

Where, '*standardised*' refers to the process of obtaining the gross value of production (GVP) following a three- step- process that is: (i) select a base crop - typically the internationally traded crop covering the largest area - and convert all yields to '*equivalent*' on the basis of the specific crop yield multiplied by the ratio of the specific crop price to the base crop, at farm gate; (ii) multiply the equivalent yields by the percentage area under each crop to give the productivity equivalent per hectare of the cropped area for each crop and add them up; (ii) multiply the production equivalent per hectare by the market price of the base crop to obtain the standardised GVP.

Production Per Unit Command (US\$/ha) = $\frac{\text{Standardised gross value of production}}{\text{Command area}}$

Production Per Unit Irrigation Supply (US\$/m^3) = $\frac{\text{Standardised gross value of production}}{\text{Diverted irrigation supply}}$

Production Per Unit Water Consumed (US$/m^3) = $\frac{\text{Standardised gross value of production}}{\text{Volume of water consumed}}$

Where, the denominator includes ET, non-beneficial ET, and losses to sinks. This indicator measures the contribution of the irrigation activity to the economy related to the consumption of the increasingly scarce water resource. Under conditions where the water resource is not necessarily scarce, the indicators useful to judge whether there is enough water that can be utilised downstream or transferred somewhere else.

Gross Return on Investment (%) = $\frac{\text{Standardised gross value of production}}{\text{Cost of irrigation infrastructure}}$

Where, the cost of the distribution system refers to the estimated current cost of construction for an equivalent delivery system.

Financial Self- sufficiency (%) = $\frac{\text{Water Charges}}{\text{Cost of O\&M}}$

Where, water charges include potential revenues from all types of fees related to the water service; and the O&M costs are based on the accounts of either the agency or WUA, which ever is appropriate. Where farmers themselves undertake individual or collective O&M, the costs should be identified and quantified.

Appendix 1.6.1 Summary of flow data collection activities

Scheme name	Block	Area (ha)	Number of Farmers	Irrigation records	Water or flume records
Deure	A	31.6	46	Yes-Water bailiffs and few farmers	yes
	B1	60.8	95		
	B2	57.5	85		Yes-portion
	B3	38.2	51		
	C	57.8	85		Yes-portion
	D1	29.1	36		
	All	275	398	Yes	Yes - 1 water controller
Chakowa		87	115	All - 2 water bailiffs (cyclone later)	Yes - 2 water bailiffs
Mutema-sprinkler	B1(90)& B11(90)	180 (B11 damaged mid-way)	253	All - 4 Agritex water bailiffs	Yes - daily DWD pump operator
Bonde-	A(160) &C1(100)	260	260	Yes – few farmers	Yes - DWD pump operators
Musikavanhu-block A1		72	60	Yes-group leaders & some farmers	Yes - farmers pump operators
Mpudzi (Chipendeke)	Upper block	25	25	Yes- few farmers	Yes-20/12/99 to 15/2/00
Mpudzi (Chipendeke)	Lower block	25	25	Yes- few farmers	Meter damaged then cyclone

Appendix 8 Table 8.5.1 Mpudzi daily irrigation practice-typical plotholder (1ha) self recorded experience

Farmer	Date	a.m.												p.m.												Hours per position	Comments
Saurowe		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12		
	17-3-99						3b	3b	3b	3b	3b	3b	3b	3b												1,5	early weeding
b=beans	18-3-99																										
planted 12/03/99	19-3-99																										
area=0.4ha	20-3-99																										
p=peas	21-3-99																										
planted 29-30/04/99	22-3-99																										
area=0.4ha	23-3-99																										
w=wheat	24-3-99																										
planted 21/04/99	25-3-99																										
area=0.2ha	26-3-99																										
	27-3-99																										
3b=3 sprinklers	28-3-99																										
in bean plot	29-3-99																										
	30-3-99																										
	31-3-99																										
	1-4-99								3b3n	3b3n	3b3n	3b3n	3b3n	3b3n	3b3n	3b3n	3b3n	3b3n	3b3n							2	early weeding
	2-4-99													2b	2b	2b										1,5	early weeding
	3-4-99																										
	4-4-99																										
	5-4-99						4b	4b	4b	4b	4b	4b	4b	4b	4b	4b	4b	4b	4b	4b	4b	4b				3	soil moisturing
	6-4-99																										
	7-4-99																										
	8-4-99																										
	9-4-99																										
	10-4-99						1b	1b	1b	1b	1b	1b	1b	1b	1b	1b	3b	3b	3b							2	fertilizer dissolving
	11-4-99						3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b									3,5	
	12-4-99																										
	13-4-99																										
	14-4-99						3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps							6	land prep.
	15-4-99						2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps				3	land prep.
	16-4-99						4b	4b	4b	4b	4b	4b	4b	4b	4b	4b	4b	4b	4b	4b	4b	4b				3	soil moisturing
	17-4-99													2b	2b	2b	2b	2b	2b							2,5	proper growth
	18-4-99																		4ps	4ps	4ps	4ps	4ps	4ps	4ps	6	land prep.
	19-4-99									1b	1b	1b	1b	1b												2	
		4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps									6	land prep.
	20-4-99						2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b					3	proper flowering
	21-4-99						3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b				4	podding
	22-4-99						3b	3b	3b	3b	3b	3w	3w	3w	3w	3w	3w	3w	3w							3	wheat seed germination
	23-4-99										2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b				4,5	enhance podding
	24-4-99							4b	4b	4b	4b	4b	4b	4b	4b	4b	4b	4b	4b	4b	4b	4b				4,5	
	25-4-99									2b	2b	2b	2b	2b	2b	2b										6	avoid sun scotching
	26-4-99									2b	2b	2b	2b	2b	2b	2b										6	
							2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w									3	wheat germination
	27-4-99									2b	2b	2b	2b	2b	2b	2b										6	
	28-4-99									2b	2b	2b	2b	2b	2b	2b										6	
	29-4-99																										
	30-4-99						2w	2w	2w	2w	2w	2w	2w	4ps	4ps	4ps	4ps	4ps	4ps							3.5 w and 2 ps	peas land prep.& wheat
	1-5-99						4ps	4ps	4ps	4ps	4ps																germination&dissolving fert.
	2-5-99																										
	3-5-99																					3b	3b	3b	3b	6	
	4-5-99	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b		2ps	2ps	2ps	2ps	2ps	2ps	2ps	3	crop planted
	5-5-99	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps								needs water
												1w	1w	1w	1w	1w	1w	1w	1w	1w						3	water for just germinated wht.
	6-5-99				2ps	2ps	2ps	2ps	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	12	plants at maturity
	7-5-99	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b								hence need more water
	8-5-99																										
	9-5-99				4ps	4ps	4ps	4ps	4ps	4ps																4	crop germinating water
	10-5-99					2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w				4	to avoid complications
	11-5-99												2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	6	
	12-5-99	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	6	
	13-5-99	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b							6	
	14-5-99																										
	15-5-99						4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps							3	germinating
	16-5-99																										
	17-5-99							convenience irrigation break																			
	18-5-99																										
	19-5-99																										
	20-5-99												3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	5	germinating
	21-5-99	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	10	final touches
	22-5-99	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	10	
								1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	4	wheat just germinating needs
	23-5-99	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b	3b													10	water for growth
		1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w															
	24-5-99																										
	25-5-99								convenience irrigation break																		
	26-5-99																										
	27-5-99											1w	1w	1w	1w	1w	1w	1w	1w							4	
	28-5-99							2w	2w	2w	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps					5	easing cultivation
	29-5-99						4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps					3	and weeding
	30-5-99						4ps	4ps	4ps	4ps	4ps															5	easing cultivation
	31-5-99																										
	1-6-99						2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2b	2b	2b	2b	2b	2b	2b	5bn/3ps	easy uprooting bns
	2-6-99	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	6	
				2ps	2ps	2ps	2ps			2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	4,5ps & 5 wht	peas weeded hence water
	3-6-99	2w	2w	2w	2w	2w	2w	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	1b	1b	1b	1b	1b	1b	6	AN apllied to wheat so water
				2ps	2ps	2ps	2ps																			4,5	
	4-6-99	1b	1b	1b	1b	1b	1b																			6	beans finished
	5-6-99																										

Farmer	Date	time a.m. 1	2	3	4	5	bns 6	7	8	9	10	11	12	p.m. 1	2	3	4	5	6	7	8	9	10	11	12	Hours per position	Comments
Saurowe																											
b=beans	6-6-99						1ps	1ps	1ps	1ps	1ps	1ps	1ps	1ps	1ps	1ps	1ps	1ps	1ps	1ps	1ps	1ps	1ps	1ps	1ps	4	sparce water due
planted 12/03/99	7-6-99	1ps	1ps	1ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps		2w	4,5	to early growth stage
area=0.4ha	8-6-99	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w															
p=peas	9-6-99																										
planted 29-30/04/99	10-6-99								convenience irrigation break																		
area=0.4ha	11-6-99																										
w=wheat	12-6-99																										
planted 21/04/99	13-6-99																										
area=0.2ha	14-6-99																4ps	4ps	4ps	4ps	3w	3w	3w	3w	3w	3ps&8wht.	sparce watering
	15-6-99	3w	3w	3w	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps							4,5	and low temperature
3b=3 sprinklers					2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w											
in bean plot	16-6-99																										
	17-6-99								convenience irrigation break																		
	18-6-99																										
	19-6-99																										
	20-6-99								4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	6 and 9	
	21-6-99	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps													6	
										1w	1w	1w	1w	1w	1w	1w	1w	1w	1w								
	22-6-99	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w		
	23-6-99	1w	1w	1w	1w	1w	1w																				
	24-6-99																										
	25-6-99															4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	7	crop geeting to
	26-6-99	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps							6	flowering hence
	27-6-99																										more frequent
	28-6-99								1w	1w	1w	1w					1w	1w	1w	1w	1w	1w	1w	1w	1w	4	watering for proper
	29-6-99	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	7	flowering and podding
																	1w	1w	1w	1w	1w	1w	1w	1w	1w	8	wheat crop tasseling needs
	30-6-99	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps															3	
		1w	1w	1w	1w	1w	1w	1w	1w																	3	frequent watering
	1-7-99																										
	2-7-99								convenience irrigation break																		
	3-7-99																										
	4-7-99							4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps							3	
									2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	10	
	5-7-99							4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps							3	
		2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	5	
	6-7-99							4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps							3	
		2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w												
	7-7-99								convenience irrigation break																		
	8-7-99																										
	9-7-99											4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps							3,5	
	10-7-99							4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps								3,5	
	11-7-99																										
	12-7-99																										
	13-7-99											4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps							3,5	
															2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	10	
	14-7-99																4ps	4ps	4ps							7	
		2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	8	
	15-7-99	2w	2w	2w	2w	2w																					
	16-7-99								convenience irrigation break																		
	17-7-99																										
	18-7-99																				4ps	4ps	4ps	4ps	4ps	8	crop almost full
	19-7-99	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps						mature stiil need
										2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	11	
	20-7-99	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w						6,5	water for proper
	21-7-99																										filling and more
	22-7-99								convenience irrigation break																		flowering and better
	23-7-99																										podding
	24-7-99																										
	25-7-99						4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	4ps	8	
								2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	8	wheat crop getting to
	26-7-99	4ps	4ps	4ps	4ps	4ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps														maturity needs water for
		2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w											8	proper seed filling &
	27-7-99																										and full development
	28-7-99							3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	2ps	2ps	2ps	2ps	2ps	9 and 5	
	29-7-99	2ps	2ps	2ps	2ps			3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps									5	
	30-7-99								2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	8,5	
	31-7-99	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w	2w								8,5	
	1-8-99																				2ps	2ps	2ps	2ps	2ps	5	crop now at harvest
																			1w	1w	1w	1w	1w	1w	1w	12	
	2-8-99	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	8	further watering for
		1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	7	
	3-8-99	2ps	2ps	2ps	2ps																						continued flowering
		1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w								6	
	4-8-99										2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	3,5	and better podding
	5-8-99	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps								
	6-8-99						2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps							2,5	
	7-8-99						2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps	2ps							2,5	
									1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	6	
	8-8-99	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w	1w								5,5	
	9-8-99							3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps							4	
	10-8-99							3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps	3ps									marketed 5/08 to 31/08
	11-8-99																										

REFERENCES

ABHAYARATNA, M.D.C, VERMILLION, D., JOHNSON, S.; PERRY, C., (EDS.).(1994)
Farmers management of ground water irrigation in Asia: Selected paper from a south Asian Regional Workshop, Colombo, Sri Lanka IIMI.

AGRITEX (2001)
Smallholder operation strategies. Agritex internal document prepared for presentation to Ministry of Agriculture.

ALLAN TONY (1998)
Moving water to satisfy uneven global needs: "Trading" water as an alternative to engineering it, ICID Vol.47. no. 2, pp 1-8.

AHEEYAR M.M.M. AND L.E.D. SMITH (1998)
Participatory irrigation management in Sri Lanka: Lessons of experience, ICID Journal vol. 47 no.2 pp77-85.

ALBINSON B. (1996)
Some design approaches for structured irrigation systems with special reference to proportional division hydraulics. Mimeo.

ANKUM, P. (1992)
Classification of control systems for irrigation*:* In *Advances in planning, design and management of irrigation systems as related to sustainable Land use*. Volume 1 edited by Feyen Jan. Mwendera Emmanuel and Badji Moussa. Published by Centre for Irrigation Engineering, K.U Leuvan Belgium. Printed by ACCO, Leuven, Belgium pp 265-274.

AISENBREY JR.A.J., R.B. HAYES, H.J WARREN, D.L. WINSETT AND R.B.YOUNG (1978)
Design of small canal structures. US Bureau of Reclamation.

BAARK ERIK AND UNO SVENDIN (1988)
Man, nature and technology: Essays on the role of ideological perception. Basingstoke: Macmillan.

BALL JOHN (1984)
The effective use of risky water supplies for irrigation. In: Blackie M.J.(ed) pp 99-104. op.cit.

BIRD J.D. AND P.W.K. GILLOT (1992)
A quantitative review of adequacy and equity indicators for irrigation system distribution, In: *Proceedings of the International Conference on Advances in Planning, Design and management of Irrigation Systems as related to Sustainable Land Use*, Leuven, Belgium.

BLACKIE M.J. (ED) (1984)
African regional symposium in smallholder irrigation, 5-7 September 1984, Hydraulics Research, Wallingford/University of Zimbabwe, Harare.

BOS, M.G. AND J. NUGTEREN (1990)
On irrigation efficiencies. Wageningen, The Netherlands: International Institute for Land Reclamation and Improvement.

BOS M G, D. H MURRAY-RUST, D. J MERREY, H.G JOHNSON, W.B SNELLEN (1994)
Methodologies for Assessing Performance of Irrigation and Drainage Management: *Irrigation and Drainage Systems*. Vol 7 No. 4: pp 231-261

BOLDING A (1996)
Caught in the catchment: Past, present and future of Nyanyadzi water management. Paper presented at the *University of Zimbabwe/ZIMWESI Workshop on Water for Agriculture: Current practices and future prospects*, 11th to 13th March 1996, Mandel Training Centre, Marlborough, Harare.

BURTON M.A AND R.P. HALL (1999)
Asset management for irrigation systems: addressing the issues of serviceability. *In: Irrigation and Drainage Systems* 13:145-163.

CARRUTHERS, I AND J. MORRISON (1994)
Irrigation maintenance strategies; A review of issues, A contribution to the MAINTAIN project Maintenance strategies of irrigation systems in developing countries: GTZ, Wye College.

CARTER, R. AND KAY, M. (1984)
Appraisal of small-scale irrigation developments in Blackie (ed.) *op.cit* pp370.
CHANCELLOR F AND N.J HASNIP (2001)
Creating sustainable smallholder irrigated farm business, Proceedings of a workshop held at Hoedspruit, Northern province, South Africa June 25-29 2001 ABXΔ HR Wallingford.
CHIDENGA E. AND VINCENT, L (2003)
Technology choices, institutional change and technology care in irrigation management in Zimbabwe, in Moll, H and Manzungu, E (ed) op.cit.
CLEMMENS, A. J. (1987)
Delivery system schedules and required capacities. *In Planning. operation, rehabilitation and automation of irrigation water delivery systems,* ed. Darrell D. Zimbelman, pp 18-34. Proceedings of a Symposium sponsored by the Irrigation and Drainage Division of the American Society of Civil Engineers and the Oregon Section, July 28-30, 1987. Portland, Oregon: ASCE.
CHECKLAND P AND J SCHOLES (1990)
Soft systems methodology in action. John Wiley and Sons,
CHIMBARI, M.J, NDHLOVU, P.D, NDLELA, B.SHAMU S., CHANDIWANA, S.K. AND MAPIRA, W (2001)
Schistomiasis control measures for small irrigation schemes in Zimbabwe: Evaluation of Mushandike irrigation scheme DFID BRI 323(1)
CORNISH GEZ (1998)
Modern Irrigation Technologies for the Smallholders in Developing Countries, Intermediate Technology Publications in association with HR Wallingford
DEBRON E (1999)
Calibrating the fayoum weir in the Musikavanhu irrigation system. Mimeo
DIEMER, G. (1997)
Agritechnology and anhtropology: The case of two types of sprinkler systems. APAD Bulletin 13, pp 79-98.
DIEMER, G AND F.P HUIBERS (EDS) (1996)
Crops, people and irrigation: Water allocation practices of farmers and engineers, London: Intermediate Technology Publications Ltd, .
DIEMER, G AND J, SLABBERS (EDS) (1992)
Irrigators and engineers, Amsterdam: Thesis Publishers.
DOORENBOS J, AND W.O PRUIT (1988).
Irrigation and Drainage Paper Number 24 – Crop Water Requirements. FAO Rome
DOSI, D (1982)
Technological paradigms and technological trajectories, Research Policy 11:pp 153.147-162.
FAO-SAFR (2000)
Socio-economic impact of smallholder irrigation development in Zimbabwe: case studies of ten irrigation schemes. Food and Agriculture Organisation Sub-Regional Office for East and Southern Africa (SAFR),
FERGUSON E. S (1992)
Engineering and the mind's eye
GOZ (1994)
Mutema feasibility and design report. Mimeo
GOZ (1992)
Bonde feasibility and design report.. Mimeo.
GOZ (1993)
Mpudzi feasibility and design report. Mimeo.
GKW CONSULT, HUNTING TECHNICAL SERVICES AND B. COLQUHOUN, H. O'DONNELL AND PARTNERS (1985)
Rehabilitation and development of small scale irrigation in schemes in communal lands vol.111 Feasibility study Devule Final report. Government of Zimbabwe Ministry of Lands Resettlement and Rural Development Department of Rural Development, KFW.

GREENLAND, D. J AND D.H MURRAY-RUST (1986)
Irrigation in humid areas - Scientific aspects of irrigation schemes: A Royal Society discussion. Published by Royal Society, pp 83-103.

HALSEMA G.F VAN, (2002)
Trial and retrial: The evolution of irrigation modernisation in NWFP, Pakistan, PhD thesis, Wageningen: Wageningen Agricultural University.

HOFWEGEN P.J. M VAN (1999)
Asset management programmes for financial planning and management in irrigation and drainage, In: Irrigation and Drainage Systems 13 volume 2, pp 131-143.

HORST LUCAS (1990)
Interaction between technical infrastructure and management, ODI/IIMI Irrigation Management Network Paper (90/3b).

HORST LUCAS (1998)
The dilemmas of water control: considerations and criteria for irrigation system design International Water Management Institute/ Wageningen Agricultural University.

HOWSAM, P. AND CARTER, R. (EDS)1997
Water policy: allocation and management in practice. London: E&F Spon.

HUNGWE A (1984)
Soil surveys for smallholder irrigation: some observation from Zimbabwe in Blackie (ed.) m*op.cit*.

HUNT R.C. (1989)
"Appropriate social organization? Water users associations in bureaucratic canal irrigation systems" *Applied Anthropology*, 48 (1): pp79-90.

IFAD (1997)
Republic of Zimbabwe Smallholder Irrigation Support Program Formulation Report, Volume II: Working Papers, GOZ.

JIMAT (2000)
Agro-economic study: Musikavanhu and Nyanyadzi South irrigation schemes, Department of Agricultural and Technical and Extension Services (MOLA) and Commission of the European Union. Draft.

JURRIENS M. AND K.P.JAIN (1993)
Maintenance of irrigation and drainage systems: Practices and experience in India and the Netherlands, ILRI, WALMI.

KAY, M (1986)
Surface irrigation system practice, Cranfield Press UK.

KNEGT J. AND L. VINCENT (2001)
From open access to access for all: Restarting challenges in designing groundwater management in Andra Pradesh, India, in *Natural Resources Forum*, 25:pp 321-331.

KELLER JACK AND RON D. BLEISNER (1990)
Sprinkler and trickle irrigation. Van Nostrand Reinhold, New York.

KELLER JACK (1990)
"A wholistic approach to irrigation scheme water management". In Sampath K. and Robert A. Young (ed). *Social, economic and institutional issues in third world irrigation management: S*tudies in Water Management Policy and Management, No. 15. Westview Press, Boulder Colorado.

KELLY WILLIAM W. (1983)
Concepts in the anthropological study of irrigation, American Anthropology vol. 85, pp 881-885.

KLOEZEN WIM H. (2002)
Accounting for water: Institutional viability and impacts of market-orientated irrigation interventions in central Mexico Ph. D thesis Wageningen Agricultural University.

LANKFORD, B. A. AND J. GOWING (1996)
Understanding water supply control in canal irrigation systems: analysis of irrigation water control, in. Howsam P. and R. Carter (eds) op. cit.. pp 187-189.

LANKFORD B.A. AND J. GOWING (1997)
Providing a water delivery service through design management interactions and system management. In: Howsam P. and R. Carter, op.cit pp 239-245.

LEEUWIS, C., LONG N. AND M. VILLAREAL (1991)
Equivocations on knowledge systems theory: an actor –oriented critique, In Kuiper, D and N. Roling (eds), Proceedings of the European seminar on Knowledge Management and Information Technology, WAU, Dept. of Extension, pp 21-29.

LEEWIS, C. (2003, forthcoming)
Rethinking innovation and agricultural extension, in Moll, H. and Manzungu, E. (eds*) op.cit.*

LEVINE GILBERT AND E. WALTER COWARD, Jr (1989)
Equity considerations in the modernization of irrigation systems ODI/IIMI Irrigation Management Network Paper 89/2b.

MAGADLELA, D (2000)
Irrigating lives; development intervention and dynamics of social relationships in an irrigation project, Ph. D thesis Wageningen Agriculture University.

MAKADHO, J. M. (1994)
An analysis of water management performance in smallholder irrigation schemes in Zimbabwe (D.Phil Thesis University of Zimbabwe unpublished).

MAKADHO J.M. (1990)
The design of farmer managed irrigation systems: experiences from Zimbabwe ODI/IIMI Irrigation Management Network Paper 90/1d.

MAKOTORE N.L. (2002)
The interaction of technology with farmers practices at Negomo irrigation scheme, a sprinkler irrigation scheme in Zimbabwe. A tale of contradicting beliefs. MSc thesis Wageningen University (pp82, 88, 121)

MAKWARIMBA, E AND VINCENT, L. (2003, forthcoming)
Job satisfaction and the organizational life worlds of extension workers in Manicaland. In Moll, H and Manzungu, E (eds) op.cit.

MAKURIRA H.M. (1991)
The Deure irrigation scheme: An investigation of water application practices on border strip plots BSc civil engineering project work (unpublished).

MADA S (2000)
Assessing the global performance of smallholder irrigation schemes: case study from Musikavanhu irrigation scheme in Manicaland Province. BSc Thesis, University of Zimbabwe (unpublished).

MALATERRE, PIERRE-OLIVER. (1995)
Regulation of irrigation a canals, characterization and classification*. Irrigation and Drainage Systems* 9: pp297-327.

MALANO, H AND M. BURTON (2001)
Guideline for benchmarking performance in the irrigation and drainage sector. IPTRID, IMWI, ICID, FAO Rome.

MALANO, H. M, N.V CHIEN AND H.N. TURRAL (1999)
Asset management for irrigation and drainage systems, In: *Irrigation and Drainage* Systems 13: 109-129

MANOR S AND J. CHAMBOULEYRON (EDS) (1993)
Performance measurement in farmer managed irrigation systems: Proceedings of an International Workshop on the FMIS Network Mendoza 12 Nov., 1991 Argentina, IMMI Colombo Sri Lanka.

MANZUNGU, EMMANUEL AND PITER VAN DER ZAAG (1996)
The practice of smallholder irrigation: case studies from Zimbabwe, University of Zimbabwe Publications.

MANZUNGU, EMMANUEL (1999)
Strategies of smallholder irrigation management in Zimbabwe, PhD thesis, Wageningen Agricultural University.

MANZUNGU EMMANUEL (2000) EDS.
Smallholder irrigation at crossroads: A dialogue on future prospects of smallholder irrigation in Zimbabwe. Proceedings of a University of Zimbabwe/ZIMWESI seminar held at the Holiday Inn, Zimbabwe 18-20 July, ZIMWESI Project, Harare.

MATSIKA NYASHA (1996)
Challenges of independence: Managing technical and social worlds in a farmer-managed irrigation scheme. In: Manzungu E. and P. van der Zaag (eds) *op.cit.*

MERRIAM J. L (1987)
Demand Irrigation schedules: in Zimbelman (eds) *op.cit*., pp68-71.

MEIJERS TON (1992)
A process approach to design: experiences in sub-Saharan Africa, In Diemer and Slabbers eds), pp143 - 154.

METERLEKAMP H.R.P (1968)
Irrigation scheduling by means of class "A" pan evaporation. *Rhodesia Journal of Agriculture:* Technical Bulletin No. 16.

MICHAEL, A. M. (1978)
Irrigation Theory and Practice. Vickas Publishing House, Delhi, India.

MINISTRY OF LANDS AND AGRICULTURE (1996).
Agricultural Policy Framework (1995 – 2000) GOZ.

MINISTRY OF LANDS AND WATER DEVELOPMENT. (1994).
Draft Agricultural Policy Strategy. (GOZ).

MOHAMED AIT-KADI (1988)
Major features of Moroccan large-scale irrigation projects: In ODI/IIMI Irrigation management network Paper (88/1d).

MOLDEN D.R, R. SAKTHIVADIVEL, C.J PERRY, C.DE FRAITURE AND W. H. KLOEZEN (1998)
Indicators for comparing performance of irrigated agricultural systems. Research report 20. Colombo, Sri Lanka: IMWI.

MOLL, H. AND MANZUNGU E (EDS) (2003, forthcoming)
Agrarian institutions between policies and local action. Harare: Weaver Press

MOLLINGA PETER .P. (1998)
On the Waterfront: Water distribution technology and agrarian change in a South Indian canal irrigation system, PhD Thesis, Wageningen Agricultural University.

MOORE MIKE (1981)
Maintenance before management: A new strategy for small scale irrigation tanks in Sri Lanka ODI/IIMI 88/2e pp5-9.

MOORHOUSE, IAN (1999)
Asset management of irrigation infrastructure- the approach of Goulburn-Murray Water, Australia, in: *Irrigation and Drainage Systems 13*: pp 165-187 Amsterdam.

MORTON JAMES (1989)
Tubewell Irrigation in Bangladesh, ODI/IIMI Irrigation Management Network Paper (89/2d).

MORIS, J. (1987)
Irrigation as a privileged solution in African development: Development Policy Review Vol. 5: pp. 99-124.

MORIS, JON R. AND DERRICK J. THOM (1990) (EDS)
Irrigation development in Africa: lessons of experience, Studies in water policy management, no. 14, Westview, Boulder.

MOYO, M (2003, forthcoming)
Sharing the waters? Participation dynamics in the Mazowe catchment, in Moll, H. and Manzungu, E (eds) op.cit.

MUGUTSO D. (1999)
Performance evaluation of a sprinkler irrigation system. BSc Ag Eng.Thesis, University of Zimbabwe (unpublished).

MUPAWOSE, ROBBIE MATONGO (1984)
Irrigation in Zimbabwe: a broad overview. In: Blackie M.J.(ed) op.cit. pp i-xii.

MURRAY-RUST, HAMMOND, D. W. BART SNELLEN (1993)
Irrigation system performance; assessment and diagnosis, International Irrigation Management Institute/International Institute for Land Reclamation and Improvement/International Institute for Hydraulic and Environmental Engineering.

NIJMAN, CHARLES (1993)
A management perspective on the performance of the irrigation subsector, PhD thesis, Wageningen Agricultural University.

OSTROM ELINOR (1992)
Crafting institutions for self-governing irrigation systems Institute of contemporary studies, San Francisco, California.

PAPANEK V(1997)
Design for the real world. Human ecology and social change. London: Thames and Hudson.

PARAJULI, U (1999)
Agroecology and irrigation technology, PhD thesis, Wageningen Agricultural University.

PAZVAKAVAMBWA, S (1984)
Management of smallholder irrigation schemes in Zimbabwe: The Committees Approach. In: Blackie, M.J. (ed) op. cit. pp421-426.

PAZVAKAVAMBWA GODFREY T (1995)
Operation and management of small scale irrigation: the case of Bonde and Deure. Paper presented at the Engineer's and Technicians Forum, Zimbabwe.

PAZVAKAVAMBA GODFREY T (2000)
The case for an Irrigation Act in Zimbabwe, in Manzungu (2000) op.cit.

PLANTEY J (1999)
Sustainable management Principles of French hydro-agricultural schemes in*: Irrigation and drainage Systems 13*:189-205.

PROCEEDINGS OF THE SOUTHERN AFRICAN IRRIGATION SYMPOSIUM (1991)
Elangeni Hotel, Durban 4-6 June 1991, The Water Research Commission (WRC) Report No TT 71/95 ISBN 86845 166 6.

PILDITCH A.G (1977)
Sprinkler irrigation: Basic principles of sprinkler irrigation design, Department of Conservation and Extension, Rhodesia.

PEREIRA LUIS S. (1998)
On farm systems: A discussion on ICID strategies, ICID Journal 1998 vol. 47 no. 2. pp 14-15.

PEREIRA LUIS S. (1996)
Inter-relationships between irrigation scheduling methods and on-farm irrigation systems, In: *Irrigation scheduling: from theory to practice*, Proceedings of ICID/FAO workshop, Sept. 1995, Rome. Water Report No. 8, FAO, pp 91-104.

PRADHAN, T.M.S. (1996)
Gated or ungated water control in government-built irrigation systems: comparative research in Nepal, PhD thesis Wageningen Agricultural University.

PLUSQUELLEC H., C. BURT, AND H.W. WOLTER (1994)
Modern water control in irrigation: Concepts, issues, and applications, World Bank Technical Paper, No. 246, Irrigation and Drainage Series, Washington.

RENAULT, D AND G.G.A GOGALIYADDA (1999)
Generic typology for irrigation systems operation: Research Report 29. Colombo, Sri Lanka: International Water Management Institute.

RAO, P.S. 1993)
Review of irrigation performance. International Irrigation Management Institute, Colombo.

REPLOGLE J.A (1987)
Irrigation water management with rotation scheduling policies. In Zimbelman (eds).*op.cit*.

RICHARDS P. (1994)
Cultivating knowledge or performance, in Hobart, H. (ed) An anthropological critique of development: the growth of ignorance. London: Routledge. p61-78

ROEP, D (2000)
Vernieuwend wekeren. Sporen van mogen en onvermogen. Circle of European Studies, Leerstoelgroep Rurale Sociologiie, Wageningen University, The Netherlands.
RONDENELLI D. A. (1993)
Development projects as policy experiments: an adaptive approach to development administration. London: Routledge, Second Edition.
RUKUNI, M.M (1984)
Cropping patterns and productivity on smallholder irrigation schemes. In Blackie, M.J. (ed) op.cit. pp 379-387.
RUKUNI, M.M., SVENDSEN M., MEINZEN-DICK R. WITH G.MAKOMBE (1996)
Irrigation performance in Zimbabwe: Irrigation Performance in Zimbabwe Project, University of Zimbabwe Harare.
SAGARDOY, J.A., BOTTRAL A, AND G.O. UITTENBOGAARD (1982)
Organisation, operation and maintenance of irrigation schemes, FAO Rome.
SAGASTI, F (1988)
Reinterpreting the concept of development from a science and technology perspective, In Baark, E and Svedin, U.(eds) *op.cit.* pp38-42.
SAVVA, P.A,, STOUTJESDIJK. A.J,, RENIER. A.M.P, AND HINDKJAER. S. V. (1991)
"Irrigation Manual Volume I" UNDP/FAO ZIM/85/004 Project.
SAVVA, A.P.; STOUTJESDIJK J.A., RENIER P.M.A. AND S.V. HINDKJAER (1994)
Irrigation Manual, second edition, UNDP/FAO/AGRITEX Project ZIM 91/005.
SAVVA (2001)
"The needs and requirements of smallholder irrigation" Paper presented at the meeting of the Irrigation Institute of Zimbabwe .
SAZS 363:1996
Zimbabwe standard specification for Irrigation equipment- irrigation sprayers and rotating sprinklers. Mimeo.
SENGE PETER M. (1990)
The fifth discipline- the art and practice of the learning organisation, . New York: Doubleday.
SENJANJE A., SAMAKANDE I., CHIDENGA E. AND MUGUTSO D (2001)
Field Irrigation Practice and the Performance of Smallholder Irrigation in Zimbabwe: Case Studies from Chakowa and Mpudzi Irrigation Schemes (unpublished).
SHANAN L (1992)
Planning and management of irrigation systems in developing countries. Amsterdam: Elsevier.
SCHEER, STEVEN (1996)
Communication between irrigation engineers and farmers: The case of project design in North Senegal, PhD thesis, Wageningen Agricultural University.
SKOGERBOE GAYLORD V. (1986)
Operations and maintenance: A learning process combining training and management. ODI/IIMI Irrigation Management Network paper 86/3d.
SKUTSCH, J. AND D. EVANS (1999)
Realising the value of irrigation system maintenance, IPTRID issues Paper No. 2.FAO Rome.
SPEELMAN J.J. (1990)
Designs for sustainable farmer-managed irrigation in Sub-Saharan Africa ODI/IIMI Irrigation Management Network Paper 90/1f.
SHEARER MARVIN N. (1987)
Developing effective extension irrigation programs with appropriate technology ODI/IIMI Irrigation Management Network Paper 87/3e.
SVENDSEN MARK (1986)
Meeting irrigation system recurrent cost obligations ODI/IIMI Irrigation Management Network Paper 86/2b.
TARDIEU H. AND J. PLANTEY (1999)
Balanced and sustainable water management: The unique experience of the regional development agencies in Southern France ICID JOURNAL vol.48 no. 1. pp 1-5.

THOMPSON A.J, CHIMBARI M.J, CHANDIWANA S.K, NDLELA B AND CHITSIKO R.J (1996)
Control of schistosomiasis: A practical guide for irrigation development. HR Wallingford Report 78.

TIFFEN MARY (1987)
The dominance of the internal rate of return as a planning criterion and the treatment of O&M costs in feasibility studies ODI/IIMI Irrigation Management Network Paper 87/1b.

TIFFEN MARY (1990)
Variability in water supply, incomes & fees: illustrations of vicious circles from Sudan and Zimbabwe ODI/IIMI Irrigation Management Network Paper 90/1b.

TIFFEN MARY AND CHARLOTTE HARLAND (1990)
Socio-economic parameters in designing small irrigation schemes for small scale farmers; Nyanyadzi case study report 3: Managing water and group activities; implications for scheme design and organisation. Report OD116, Hydraulics Research Wallingford.

TURRAL, H (1995) (EDS)
Devolution of management in public irrigation systems: cost shedding, empowerment and performance: a review. London: Overseas Development Institute.

UBELS, JAN AND LUCAS HORST (EDS) (1993)
Irrigation design in Africa: towards an interactive method, Wageningen Agricultural University/CTA, Ede.

UNDERHILL, H.W. (1984)
The roles of governmental and non-governmental organisations and International Agencies in smallholder irrigation development, In Blackie, M.J (ed) op.cit. pp 9-22.

UPHOFF, NORMAN (1986)
Improving irrigation water management with the farmer organisation and participation: Getting the process right, Studies in Water Policy and Management, No. 11, Westview Press, London.

VERDIER, J.AND J. L.MILLO (1994)
Maintenance of irrigation systems: a practical guide for system managers, ICID no. 40.

VERMILLION DOUGLAS L. (1989)
Second approximations: Unplanned farmer contributions to irrigation design ODI/IIMI Irrigation Management Network Paper 89/2c.

VERMILLION D.L. AND J.A. SAGARDOY (1999)
Transfer of Irrigation management Services: Guidelines. Irrigation and drainage paper no. 58. IWMI, GTZ, FAO, Rome.

VINCENT, L. (1995)
Hill irrigation: Water and development in mountain agriculture, London: Intermediate Technology Publications on behalf of the ODI, pp 37,74.

VINCENT, L. (1997)
Irrigation as technology, irrigation as resource: Hill irrigation and natural resource systems, Shivakoti, G. Varughese, G. Ostrom, E. Shukla, A and Thapa, G. editors. *People and Participation in Sustainable Development: Understanding the dynamics of natural resource systems* (Proceedings of an International Conference held at the Institute of Agriculture and Animal Science, Rampur, Chitwan, Nepal, 17-21 march 1996). Bloomington, Indiana, and Rampur, Chitwan. pp 39-52.

VINCENT, L. (2001)
Struggles at the social interface: developing sociotechnical research in irrigation and water management in Hebink P. and G. Verschoor eds. *Resonances and Dissonances in development: Actor, networks and cultural repertoires.* Wageningen. pp67-78.

VINCENT, L. (2003)
Towards a smallholder hydrology for equitable and sustainable water management. Natural resources Forum 27:pp 108-116.

VINCENT, L. AND MANZUNGU, E. (2003, forthcoming)
Water rights and water availability in the Lower Odzi watershed of the Save catchment, in Moll, H. and Manzungu, E. (eds) *op.cit*.

VIJFHUIZEN, C. (1998)
"The people we leave with"; gender identities and social practices, beliefs and power in the livelihoods of Ndau women and men in a village with an irrigation scheme in Zimbabwe, PhD thesis Wageningen Agricultural University.

VOS, J. M.C. (2002)
Metric Matters: The performance and organisation of volumetric water control in large- scale irrigation in the north Coast of Peru, PhD thesis Wageningen Agricultural University.

WILSON G. J. (1974)
Recommended combination of sprinkler size and spacing. Irrigation Branch Department of Conservation and Extension, Rhodesia.

WAHAJ, R (2001)
Farmers actions and improvements in irrigation performance below the mogha: How farmers manage water scarcity and abundance in a large scale irrigation system in South-Eastern Punjab, Pakistan, PhD thesis, Wageningen Agricultural University.

WALKER W. R. (1991)
Software and automation for evaluation and improving surface irrigation efficiency and uniformity, in Proceedings Of Southern African irrigation Symposium 4-6 June Elangeni hotel, Durban pp 202.

WRMS (2003)
Towards integrated water resources management: Water resources management strategy for Zimbabwe. Department of Rural Resources and Water Development Mimeo

WYNNE, BRIAN
Technology as cultural process, in Baark, E. and Svedin, U. (eds) op.cit. pp 80 -104

ZAAG, P.VAN DER (1992)
Users, operators and hydraulic structures: A case of irrigation management in Western Mexico, ODI Network Paper 19.

ZAAG, P VAN DER., (1992)
Chicanery at the canal: Changing practice in irrigation management in Western Mexico, Ph D thesis, Wageningen Agricultural University, pp 202-204.

ZAWE, C (2000)
Coping with operation and maintenance at farmer-managed sprinkler irrigation schemes: a case study of an irrigation management turnover experiment at Msengezi schemes in Mashonaland West Province of Zimbabwe, MSc thesis, Wageningen Agricultural University.

ZIMBABWE (1994)
Irrigation policy and strategy: Ministry of Lands, Agriculture and Water Development, Harare.

ZIMBELMAN D 1987 (EDS)
Planning, operation, rehabilitation and automation of irrigation water delivery systems. Proceedings of a Symposium sponsored by the Irrigation and Drainage Division of the American Society of Civil Engineers and the Oregon Section, July 28-30, 1987. Portland, Oregon: ASCE.

ZIREBWA JOSEPH (1997)
Evaluation of the technical performance of small holder irrigation schemes in Zimbabwe: Musikavanhu case study, MSc Thesis, International Institute for Infrastructure Hydraulic and Environmental Engineering (IHE).

SUMMARY

Smallholder irrigation in Zimbabwe today is recognised to have a series of challenges of sustainability, profitability and management capacity. While many problems have been described, a framework is still lacking to analyse why a high level of state involvement and external funding has failed to create sustainable schemes and also provide a basis for new reflection and action to restore viability. One concept fundamental to such an initiative is "terotechnology", or the capacity to care for a scheme. This concept is linked to conscious thinking about design of a technological system, and its management so that the infrastructure is cared for through operations and maintenance (O&M). There is a dominance of preferred choices of designers rather a conscious recognition of design for farmers, and their locality and environment.

This thesis contributes to the objective of improved understanding of design choices in Zimbabwe, to allow for a learning approach. It aims to provide a new systematic reflection of how irrigation technology and management systems are linked together in water delivery, and must be studied together with the local people also to design appropriate technological care. Irrigation designers have tended to concentrate on optimising perceived engineering standards or goals, to attain optimum distribution and application performance as indicated by recognised performance indicators like efficiency and equity. Design for adequacy, reliability and security of water delivery is not given priority. It is also important to compare the designed, 'anticipated' outputs against the actual outputs, and how the water demands, and income generated are shaped by or shape operation and maintenance. There is, in particular, no documented experience on the sustainability of overhead irrigation systems across generations of users and therefore it is necessary to critically monitor their performance.

Chapter one has reviewed relevant debates with respect to operation and maintenance of smallholder schemes. Performance indicators have been discussed as one way of providing proxies for assessing the adequacy of designs, operation and maintenance, both to show farmers' knowledge and shaping water delivery as well as technical levels achieved. It has outlined a theoretical approach, combining a sociotechnical analysis with soft systems methodology, to focus on the concept of leverage. The theoretical framework essentially provides for differentiating the water delivery subsystem (WDSS) that comprises the physical continuum of water flow from the source to the crop, from the management support subsystem (MSSS) being the institutions and actions that sustain the WDSS. The basic outputs are the water delivery performance, production and environmental sustainability. The relationship between the WDSS and the MSSS is that of leverage, that is finding the actions that provide for most of the desired outputs. Leverage through contingent action by local actors adds to the outcomes from formal systems, to show where there are gaps in these systems and options for future change.

To understand these technology and management choices and interactions, this thesis examined the range of irrigation system technologies found in smallholder irrigation in Zimbabwe; how and why they differ in technology and management arrangements; and how well, and why, can current management systems undertake operations and maintenance and leverage effective water distribution in different irrigation systems. A case study approach was selected with a focus on six systems that represented core examples of the changing technology trajectory of smallholder irrigation in Zimbabwe. The case study methodology was selected because of its powerful effect in bringing out the everyday realities of technological design, operation and maintenance at each irrigation scheme in its social setting. By studying these live forms one can reasonably anticipate the creative output of future designs with respect to O&M.

Chapter two shows how gaps and weaknesses in institutional interfaces at local, regional and state level in Zimbabwe have failed to provide either a base for reflection and coherent learning about technology choices, or to put a support system in place for terotechnology. Instead irrigation service institutions show a technological repertoire heavily influenced by international donor preferences and scientific debates - and little capacity to look coherently at what makes an irrigation system work. Forced change has been the fate of smallholder irrigation management, under interventions for technical and institutional streamlining rather than 'making systems work'. There has been a shift of thinking that led to a system of irrigation manager, work gang and strong fee collection system being replaced by Irrigation Management Committee without formally defined powers. In this process little attention has been given to the issue of effective control or the effective provision of resources for O&M.

Choices of technology were made without insight into their institutional requirements given local social needs, management capacity and the profitability of irrigation in the region. Originally smallholder systems were developed under surface irrigation sourced by river weir intakes, but systems were sometimes made too large for the supply or extended into less favourable lands also often a considerable distances from the source. A marked shift in technological interventions came in the 1990s, with greater use of pumped lift irrigation sources, the incorporation of fayoum weirs in surface water distribution and the introduction of draghose sprinkler systems in overhead systems. The starting point for both design and management interventions in the last has been an attempt to meet the crop water requirements (CWR). The draghose systems have placed operation and maintenance responsibility onto individual farmers first, and corporate structures as second choices. Proportional systems on the other hand do not view meeting of the CWR as a primary design objective. Therefore there is currently no common ground or agreed set of objectives in the various design and management interventions. The major irrigation related institutions, Agritex and DWD, both found themselves with large pump schemes that neither government nor farmers alone could finance. The interlocking institutions in irrigation and water management need to be made to work better amongst themselves and improve their way of working with farmers.

Chapters three and four examine the first generation of smallholder system design - the surface system fed by a weir and often incorporating night storage dams - at Chakowa and Deure. **Chapter three** studies Chakowa, once considered one of the best working systems but actually revealed to be a system fighting decline in operational manpower and in equity of water delivery. The study reveals that the water supply and weir repair at Chakowa is beyond the capacity of the farmers, local government institutions and those directly in control of irrigation. The farmers have demonstrated capacity to handle minor operation and repair issues at the weir. However, choices in the system layout and control technology have allowed strong head end-tail end disparities to emerge in water access. The inequalities in water delivery are fuelled by head-end horticultural production that gives these farmers good incomes, while tailenders are relegated to supplementary irrigation for virtual subsistence production. This has restricted the collaboration and social networking necessary for effective emergency maintenance. Beyond rethinking fees, representation and equitable access, other main future points of leverage for Chakowa are: stabilisation of supply**,** provision of a permanent abstraction point and improved water control at field level taking note of the different soils. Most of the problems seem to be emanating from scarce and unreliable supplies that cannot be managed.

The Deure irrigation scheme discussed in **chapter four** presents a case of a scheme where the community and government have worked together to progressively improve a water delivery service. The development of the early green maize market has created a sharp peak crop demand that has put pressure on farmers to concentrate planning. They have responded by appropriating the annual maintenance of the weir and conveyance canal to meet the planting date. Through experience and participation at peak season they have also adopted “pulse” deficit irrigation, using the flexibility of the system to supply two hydraulic units at one time. The key technical points that provide leverage at Deure are the simple rock founded weir, gravity canal conveyance, and flexible gated distribution canal that supply a secure stabilised water delivery. Co-operating government and farmer institutions manage these areas to grow livelihood crops and commercial crops. The supporting institutions work in harmony to deal with any shortfalls in the WDSS. Government authority in everyday water allocation is respected and supported by local institutions. Nevertheless, the scheme has block level problems like competition for night irrigation, bilharzia risks and snails in canals, poor drainage and infrastructure maintenance, although these do not have significant affects on farmers’ livelihoods.

Chapters five and six look at systems sourced by pumps, supplying a pressurised overhead system at Mutema, and a surface system controlled by fayoum weirs at Musikavanhu. **Chapter five** analyses water delivery at Mutema, where the need both to expand the scheme and stabilise the water supply resulted in adoption of borehole pumping. A pressurised overhead WDSS was installed with the belief that it would enhance the water management and irrigation of marginal sandy soils. Therefore in 1970 the scheme made an early two-step jump along the trajectory, from a simple gravity run-of-river scheme of the 1930s to a pumped supply with pressurised distribution and overhead application. Confronted with unforeseen salinity problems in the borehole water, a looped design was adopted with an operational requirement to operate the borewells as a closed system. Low borewell reliability has frustrated this solution. Faced with increasing salinisation farmers now openly discourage each other from growing sensitive crops especially beans. Water bailiffs manage the laterals from experience, to raise the system pressure to a point where the sprinklers start turning but they do so at low uniformity of application. Farmers have remained as passive recipients of technological interventions, have and treated renovation programmes with mistrust. Attempts at Irrigation Management Transfer have not been welcome at Mutema. The short-term leverage therefore lies in narrowing the technology-management gap between farmers, local staff and agency staff, and irrigation equipment manufacturers and suppliers. The long-term leverage lies in providing a stable water source with a robust water delivery at Mutema.

The technology chosen for Musikavanhu described in **chapter six,** created high demands for both financial and technical skills to operate the pumped borewell and surface system. A well-supported training program designed to support adoption and handover of sophisticated WDSS failed to build farmers’ confidence in the system as an FMIS. Economic not hydraulic reasons informed farmers' decisions on water regulation, to minimise pumping costs. Performance results could not be interpreted correctly without understanding these reasons to control water supply. The fayoum weir proportional system is functional and effective as evidenced by all groups growing the same crops at the same time. However there remains a need to build institutions that provide for transparency, and encourage farmers to pay maintenance fees for repair of the simple canal, road, drain and fence system. A longer term leverage to get sustained water delivery for the Musikavanhu scheme lies in the development of a gravity canal supply system linked directly to the reservoirs Ruti, Rusape and Osborne. The potential benefit of this network approach are: a reduction or elimination of electricity operating costs and unnecessary use of pumps, increased control of Save River siltation and flooding problems, and adoption of a new conjunctive use approach to borehole water use to enhance delivery security for smallholders in Zimbabwe.

Chapters seven and eight represent the latest elements of the technological trajectory of Zimbabwe, in piped and pressurised systems. Bonde, discussed in **chapter seven,** represented several brave new elements of the technological trajectory in: use of pressurised equipment offering flexibility for cultivation practices in the field; two-stage pumping; a large-scale system (for Zimbabwe); and farmer management. Yet in reality the needs of the system and its leverage were never thought through. The developers assumed that after construction, farmers would spontaneously provide an appropriate MSSS focused on objectives of high water efficiency, by practising modern concepts of crop-based scheduling and individual flexible cropping. Energy costs were not properly considered. An analysis of the problems revealed that pump selection was inappropriate and there were several design lacunae relating to managing silt, pump repair options and feasibility of mobilising energy costs. New farmers have tended to underestimate the labour input and perseverance required to fight the "silt war" at the pump intake. Lack of water delivery security - mainly due to pump closure and breakdowns - clearly dominated the Bonde farmers' agenda, and masked the benefits of source stabilisation due to the Ruti dam (that did happen at Deure) The local people see feasible leverage locally to build a weir and gravity canal system to eliminate the pumps, and I think this is where to foster organic learning and build on existing internal institutional memory. Designers need to understand that farmers and local agencies need time to understand and build strength through do-able tasks.

Uniformity of application is probably the biggest benefit that can be derived from modern piped and pressurised systems. Unfortunately **chapter eight** shows that the draghose system at Mpudzi system is performing at a level lower than anticipated, although its gravity supply does not present energy costs. The main causes are the maintenance regime and wind effects. Farmers are already contributing to low pressure by use of bigger diameter hosepipes and sprinklers of larger nozzle diameter than recommended, in order to obviate night irrigation and wind effects. To deal with water scarcity, the meetings and negotiations at Mpudzi are similar to those other schemes - leading to hydraulic units irrigating on alternate days. The lower block at Mpudzi has a modern technological system, and a reliable water supply with no institutional problems, but cannot be productive due to low fertility of sandy soils.

There is lack of institutional support to guide the users in maintenance of the sophisticated system. Issues like distribution uniformity are too complex and not immediately important to production, with unclear solutions that call for good expert study, advice and guidance. There is need to revisit the handover process to define which responsibilities still require central support, where private companies can play a role and what farmers can manage. The benefits derived from individualised operation of the system do not necessarily ensure proper individualised maintenance of the system components.

Chapter nine provides a comparison of operation and maintenance practices alongside local management arrangement. It shows great diversity and little standard practice across systems, questioning design and hand over paradigms. The chapter also shows that farmers and local actors have built their own processes to deal with problems. Manzungu's (1999) assertions that there is contingent field water management and no scientific scheduling practice is reiterated for surface irrigation schemes and also found to pervade sprinkler systems also. The study found that choices in crop production are not only shaped by the market and livelihood requirements as observed by Rukuni (1994) but are also persistently shaped by water security. Farmers were found to undertake a **substantial amount of pre-season planning** with their role increasing as the government contribution decreases (whether by default or by design). They **eventually appropriate** the water delivery component where the simplicity of systems allows.

Where technology is sophisticated, farmers initially attempt to demystify, simplify or localise the technology on their own by requesting local experts to undertake repair and maintenance works. **'Localisation'** also involves trying to minimize costs by substituting components with familiar, easier to use or locally available materials. On failing they go into the **stage of serious engagemen**t that involves farmers talking straight to government or any service provider about their water delivery expectations. If the farmers are still not satisfied then the last crucial **stage of scheme re-design** starts. This involves farmers revising cropping programs, cutting down on irrigated area and - where this in not possible - abandoning irrigation in favour of dryland production within or outside the scheme.

The study found that government has not fostered any client-customer relationship between industry and the smallholder farmers using sophisticated technologies. There is a reluctance of farmers and farmer groups to make firm financial provisions for the purchase of appropriate skills, spares or replacement materials for sophisticated technologies. One major cause of this is confusion in the ownership structures. Farmers find no reason to adopt efficient in-field water management to save water that is later returned back to the river.

This study has shown farmers avoid payments for water and maintenance except where they see a service, and profitable livelihoods to cover costs. Where necessary, farmers share scarce water supplies on a time base, rather than resorting to flow measurement. System performance data given here shows that technology has not made very much difference *per se* to efficiency in water use: rather the performance study has been a means explore and show the interesting, innovative and sometimes exploitative actions that farmers and front-line workers take to leverage their water delivery.

The concluding **chapter ten** calls for irrigation design and development agents in Zimbabwe to rethink their engineering precepts and redirect the technological trajectory. There is a need re-establish purpose, functionality and terotechnology, through consensus and accommodation, via processes of problem identification, analysis and optimisation. There is need for consent on strategies of change that users are willing and able to pursue in water management.

It is proposed that a wider agency perspective be considered in design for future smallholder irrigation needs. Farmers and local actors want water security, designs that can be maintained, clear ownership and better regulation and control around systems. There is need to be realistic about farmer management and joint management. It is proposed that the two approaches - of service provision by private organisations and asset management by quasi government institutions - be considered simultaneously, with appropriate choices made for each system configuration, and phased in as required. It is proposed that appropriate public utilities and regulatory and control structures be legally established, and be made answerable to all members to ensure financial transparency and public accountability, that will determine their growth and sustainability. It is therefore urgent that appropriate policy and monitoring structures be built.

There remains a need to improve farmers' capacity to anticipate and progressively monitor their water use, so they become meaningful partners in water resources planning and consultation processes, in line with the WRMS to improve stakeholder participation. This might also increase farmers' capacity to utilise new technologies and manage new systems that provide for new levels of demand. However, this will not happen while farmers remain suspicious of monitoring and measurements as tools that may be used to invalidate their access to water. Mutual discussion on new techniques for asset assessment and maintenance of the water may also help rebuild terotechnology, around new public, private and civil partnerships.

Irrigation engineers in Zimbabwe need to be people who understand and are interested in how irrigation systems are used, not only how to design and construct equipment. Zimbabwe needs engineering precepts that contribute to robustness, sustainability and water security of systems for smallholder farmers, not just individualising water use.

NEDERLANDSE SAMENVATTING

(Dutch Summary)

De kleinschalige irrigatie sector in het Zimbabwe van vandaag wordt gekenmerkt door een aantal uitdagingen op het vlak van duurzaamheid, winstgevendheid en beheerscapaciteit. Terwijl vele problemen inmiddels zijn onderkend, ontbreekt het nog aan een analytisch raamwerk om te verklaren waarom een grote betrokkenheid van de overheid alsmede externe financiering niet heeft geleid tot het ontstaan van duurzame irrigatie systemen, noch tot de zo noodzakelijke reflectie en actie om tot grotere levensvatbaarheid te komen. Fundamenteel voor het laatste is het begrip “terotechnologie”, ofwel het vermogen zorg te dragen voor een stelsel. Dit begrip verbindt het ontwerp van een technologisch systeem met het beheer ervan, zodat het voortbestaan van de infrastructurele werken is gewaarborgd door middel van operationele en onderhoudsmatige activiteiten. Momenteel treden een aantal technische (ge-eikte) ontwerp criteria sterk op de voorgrond, ten koste van de expliciete erkenning van het belang van boeren-ontwerp, de lokale situatie en haar omgeving.

Dit proefschrift draagt bij aan een beter begrip van ontwerp keuzen in Zimbabwe om te komen tot een leerproces benadering. Het proefschrift verschaft een nieuwe systematische manier van reflecteren op het samenspel van irrigatietechnologie en management systemen (beheers-processen) dat resulteert in bepaalde vormen van watervoorziening. Om de juiste zorg voor een stelsel tot stand te brengen dient het bovengenoemde samenspel te worden bestudeerd in samenspraak met de lokale gebruikers. Irrigatie ingenieurs hebben de neiging zich te concentreren op ingesleten ontwerprichtlijnen die verondersteld worden zorg te dragen voor een optimale verdeling en toediening van irrigatiewater, zoals weergegeven door erkende evaluatiecriteria op het vlak van productiviteit en rechtvaardigheid. Een gepaste, betrouwbare, en gewaarborgde voorziening van water speelt een geringe rol in deze ontwerppraktijk. Ook is het van belang de geprojecteerde resultaten te vergelijken met de behaalde resultaten, en te bepalen in hoeverre de vraag naar water, alsmede het gegenereerde inkomen, invloed uitoefenen op, dan wel beïnvloed worden door, het gevoerde beheer en onderhoud. Gezien het gebrek aan documentatie over de duurzaamheid van besproeings-systemen gedurende generaties van gebruikers, is het van belang deze systemen kritisch te evalueren op hun resultaten.

Hoofdstuk 1 behandelt de relevante debatten met betrekking tot het beheer en onderhoud van kleinschalige irrigatie stelsels. Resultaat gerichte indicatoren worden hierin behandeld als een manier voor het inschatten van de geschiktheid van het ontwerp, beheer en onderhoud, om zowel boerenkennis en –kunde in het vormgeven van de waterverdeling als het behaalde technische niveau te beschrijven. Het hoofdstuk voorziet in een theoretische benadering, die een sociaal-technische analyse combineert met een ‘soft systems’ methodologie, met een expliciete nadruk op het begrip “aansturing” (leverage). In het theoretisch raamwerk wordt een onderscheid gemaakt tussen het water voorziening subsysteem (WDSS – water delivery subsystem) enerzijds en het beheers subsysteem (MSSS – management support subsystem) anderzijds. Het water voorzienings subsysteem beslaat hierbij het fysieke continuum van water zoals het stroomt van de bron naar het gewas, terwijl het beheers subsysteem de instituties en handelingen betreft die benodigd zijn om het fysieke systeem in stand te houden. De interactie tussen beide subsystemen resulteert in een bepaalde mate van watervoorziening, productiviteit en duurzaamheid. De relatie tussen beide subsystemen wordt bepaald door de mate van aansturing, oftewel die activiteiten die zorg dragen voor het behalen van de gewenste resultaten. Aansturing als gevolg van spontane acties van lokale gebruikers draagt bij aan de resultaten die behaald worden door het formele systeem. Dezelfde acties tonen de hiaten van het systeem, alsmede de ruimte voor toekomstige verandering van het systeem.

Om te komen tot een goed begrip van technologie- en beheers-keuzen, alsmede de interactie tussen de twee, behandelt dit proefschrift het gehele spectrum van kleinschalige irrigatie technologiën dat Zimbabwe herbergt, inclusief de vraag hoe en waarom die systemen verschillen in technologie en beheersvormen, en de vraag hoe goed, en waarom, huidige beheerssystemen operationele en onderhouds activiteiten ondernemen, alsmede effectieve water verdeling aansturen in de verschillende irrigatiesystemen. Hierbij is gekozen voor een 'case study' benadering betreffende een zestal systemen die exemplarisch zijn voor het veranderende technologische traject van kleinschalige irrigatie in Zimbabwe. De 'case study' methodologie is gehanteerd om de alledaagse realiteit van technisch ontwerp, beheer en onderhoud in ieder bestudeerd stelsel naar voren te brengen binnen haar sociale context. Door deze stelsels te bestuderen 'in actie' kan men de creatieve vormgeving van toekomstige ontwerpen met betrekking tot beheer en onderhoud redelijkerwijze anticiperen.

In **hoofdstuk 2** wordt aangetoond hoe bestaande hiaten en zwaktes in de afstemming van instanties op lokaal, regionaal en nationaal niveau in Zimbabwe hebben geleid tot een situatie waar geen plaats is voor reflectie en het leren van lessen over technologische keuzes, of het creëren van een systeem dat voorziet in terotechnologie. In plaats daarvan tappen de huidige irrigatie instanties uit een technologisch repertoire dat zwaar wordt beïnvloed door de voorkeuren van internationale donor organisaties en wetenschappelijke debatten – met weinig oog voor datgene wat een irrigatiestelsel doet functioneren. Gedwongen veranderingen vormen een vast onderdeel in het beheer van kleinschalige irrigatie, met nieuwe beleidslijnen die meer oog hebben voor technische en administratieve vereenvoudiging dan voor het doen functioneren van systemen. Er is een verandering opgetreden die heeft geresulteerd in het vervangen van de irrigatie manager, met onderhoudsploeg en strikte inning van water tarieven door een lokaal irrigatie beheersorgaan (Irrigation Management Committee) zonder formeel vastgelegde autoriteit. Bij dit decentraliseringsproces is weinig aandacht besteed aan de kwestie van effectief beheer en voorziening van voldoende middelen voor het ondernemen van operationele en onderhouds-activiteiten.

Technologiekeuzes zijn gemaakt zonder eerst inzicht te verwerven in de institutionele vereisten gegeven de lokale sociale behoeften, management capaciteit en winstgevendheid van irrigatie in de regio. Oorspronkelijk werden enkel kleinschalige stelsels ontwikkeld die gebruik maakten van oppervlakte water irrigatie middels een stuw en inlaatwerk in de rivier en bijbehorend kanalenstelsel. Vaak zijn deze stelsels groter dan de waterbron toestaat of worden stelsels uitgebreid op ongeschikte irrigatiegronden, soms gelegen op grote afstand van de bron. In de negentiger jaren vond een markante wijziging plaats in de gebruikte technologie: er werd meer gebruik gemaakt van pompen, fayoum verdeelwerkjes werden geïntroduceerd in oppervlakte water systemen, en in de sproeisystemen werd in toenemende mate gebruik gemaakt van zogenaamde 'draghose' (verplaatsbare) sproeiers. Uitgangspunt bij het ontwerp en beheer van de laatst genoemde technologie vormde een poging aan de waterbehoeftes per gewas te kunnen voldoen. Bij 'draghose' stelsels ligt de verantwoordelijkheid voor operationeel beheer en onderhoud in eerste instantie bij de individuele gebruiker zelf, en pas in tweede instantie bij derden. In contrast, is het bij proportionele (conventionele) irrigatiestelsels niet gebruikelijk het voldoen aan de waterbehoeftes van het gewas centraal te stellen in het ontwerp. Om die reden bestaat er momenteel geen overeenstemming of gedeelde doelstellingen in het scala aan ontwerp en beheers-interventies die worden ondernomen. De twee voornaamste irrigatie-instanties, Agritex en DWD, worden aldus geconfronteerd met grote pomp systemen die noch de overheid noch de boeren alleen zouden kunnen financieren. Het geheel aan gerelateerde instanties die actief zijn in irrigatie en water beheer zullen moeten worden bewogen beter met elkaar samen te werken en hun omgang met boeren leren verbeteren.

Hoofdstukken 3 en 4 bestuderen het ontwerp van de eerste generatie van kleinschalige irrigatie systemen in Chakowa en Deure. Deze systemen zijn oppervlakte water systemen die worden gekenmerkt door een vaste stuw in de rivier. Vaak zijn ze ook uitgerust met zogenaamde nacht reservoirs. In **hoofdstuk 3** wordt het Chakowa stelsel bestudeerd. Hoewel het ooit werd beschouwd als het best werkende stelsel, is gebleken dat het momenteel vecht tegen een gebrek aan operationeel personeel en scheefgroei in de waterverdeling. Deze studie laat zien dat de watervoorziening en het onderhoud van de stuw in Chakowa boven het hoofd stijgt van de gebruikers, lokale overheidsinstanties en degenen die direct verantwoordelijk zijn voor het irrigatiebeheer. De gebruikers zijn in staat kleine operationele en onderhouds-taken aan de stuw uit te voeren. Desalniettemin, hebben keuzes in de lay-out van het systeem en de waterbeheersing technologie ertoe geleid dat er scherpe contrasten zijn ontstaan in toegang tot water tussen de boven en benedenstroomse uiteinden van het systeem. Deze onevenredige toegang tot irrigatie water is versterkt doordat bovenstroomse boeren tuinbouwgewassen telen die hen een goed inkomen verschaffen, terwijl de benedenstroomse boeren aldus worden veroordeeld tot het gebruik van supplementaire irrigatie voor de verbouw van voedselgewassen. Dit heeft de mogelijkheden tot samenwerking en netwerken, zo hard nodig voor het tot stand brengen van effectief noodonderhoud, aanzienlijk bemoeilijkt. Naast het heroverwegen van tarief inning, gebruikers vertegenwoordiging en evenredige toegang tot water, zijn de hoofdpunten voor toekomstige aansturing van Chakowa: stabilisering van de water voorziening, het voorzien in een permanent punt voor de onttrekking van water, en verbetering van de water toediening op veldniveau met in acht neming van de verschillende bodemsoorten. De meeste problemen ontstaan echter als gevolg van de geringe en onbetrouwbare water voorziening van de bron, iets waar weinig aan gedaan kan worden.

Het Deure irrigatie stelsel is het onderwerp van **hoofdstuk 4**. Het is een voorbeeld van een stelsel waar de gebruikers en de overheid samen hebben gewerkt aan het verbeteren van de water voorziening. De opkomst van een markt voor vroeg in het seizoen geteelde groene maïs heeft geresulteerd in een hoge piek in de watervraag. Als gevolg daarvan moeten de boeren veel aandacht besteden aan de planning van hun activiteiten. Om de vroege plant datum te kunnen halen hebben de boeren zelf het jaarlijkse onderhoud van de stuw en het hoofdkanaal op zich genomen. Gebaseerd op hun ervaring en actieve participatie in het piek seizoen hebben de boeren een methode van irrigeren met tekorten (korte, snelle giften van water) ontwikkeld, waarbij ze actief gebruik maken van de flexibiliteit die het systeem biedt om twee hydraulische blokken tegelijk te irrigeren. De voornaamste technische karakteristieken die de operaties in Deure aansturen zijn de eenvoudige stuwm die verankerd is op rotsen en het flexibele aanvoerkanaal dat uitgerust is met beweegbare schotten. Aldus is het mogelijk een gewaarborgde, stabiele water voorziening te realiseren. Dit geheel wordt gezamenlijk beheerd door de overheid en boerenorganisaties, met als doel een mix van voedsel- en markt-gewassen te verbouwen. De ondersteunende organisaties werken in harmonie aan het ondervangen van gebreken in het watervoorziening subsysteem (WDSS). De zeggenschap van de overheid in het uitoefenen van het dagelijkse waterbeheer van het systeem wordt gerespecteerd en actief ondersteund door de lokale organisatie. Desondanks bestaan er problemen op blok niveau, zoals de strijd om irrigatiewater gedurende de nacht, de kans op *bilharzia* infectie door de aanwezigheid van slakken in het kanaal, en gebrekkige drainage en onderhoud van het systeem. Edoch deze problemen vormen geen serieuze bedreiging voor het levensonderhoud van de boeren.

In hoofdstuk 5 en 6 staan stelsels centraal die voorzien worden van water middels pompen. In Mutema wordt het water in een gesloten sproeisysteem gepompt, terwijl in Musikavanhu de watervoorziening geschiedt middels een kanalenstelsel dat is voorzien van zogenaamde fayoum verdeelwerkjes. In **hoofdstuk 5** wordt de watervoorziening geanalyseerd van het Mutema stelsel, alwaar de behoefte aan expansie van het stelsel en de noodzaak de watervoorziening zeker te stellen heeft geleid tot het slaan van putten waaruit het water wordt onttrokken middels pompen. Het gesloten sproeisysteem is aangelegd in de veronderstelling dat daarmee de watervoorziening verbeterd zou worden en irrigatie van marginale zandige gronden mogelijk werd. Aldus deed het stelsel twee stappen vooruit op het technologische traject van kleinschalige irrigatie ontwikkeling in Zimbabwe. Was het in de jaren dertig nog een simpel kanalensysteem dat gebruik maakte van zwaartekracht bevloeiing, in 1970 werd het uitgerust met pompen en een gesloten sproeisysteem gebruik makend van de druk die gegenereerd werd door de pompen. Geconfronteerd met onvoorziene verzouting van het putwater, is vervolgens gekozen voor een gesloten ontwerp, dat vereist dat de putten en sproeiers als één geheel in werking worden gesteld. Deze oplossing wordt echter gefrustreerd door de lage betrouwbaarheid van de watervoorziening in de putten. Door de toename van verzouting raden boeren elkaar nu openlijk af zout-gevoelige gewassen, zoals bonen, te verbouwen. De lokale ‘watermeesters’ blijken goed in staat om op basis van ervaring de druk in de sproeilijnen dusdanig te verhogen dat de sproeiers gaan draaien. De prijs voor dit soort acties is echter dat de sproeiers met wisselende intensiteit opereren hetgeen de uniformiteit van de water giften niet ten goede komt. Over het algemeen hebben de boeren de technologische verbeteringen van hun systeem ondergaan als passieve gebruikers, met als gevolg dat ze elke verbetering argwanend beschouwen. Pogingen de verantwoordelijkheid voor het waterbeheer van het stelsel over te dragen aan de boeren zijn niet in goede aarde gevallen in Mutema. De mogelijkheden voor verbeterde aansturing van het systeem op de korte termijn liggen op het vlak van het verkleinen van de technologie-beheer discrepantie tussen boeren, lokaal personeel en personeel van de overheidsdiensten, evenals de producenten en toeleveranciers van irrigatietechnologie. Verbeterde aansturing op de lange termijn kan enkel worden geëffectueerd door de ontwikkeling van een stabiele en betrouwbare bron van water voorziening.

De gekozen technologie in Musikavanhu, het onderwerp van **hoofdstuk 6**, vereist een hoge mate van financiële en technische vaardigheid, om zowel de waterputten met pomp als het open kanalenstelsel te doen werken. Een goed ondersteund trainingsprogramma om de overname van het geraffineerde systeem te bespoedigen heeft niet geresulteerd in de beoogde werking van het systeem als een door boeren beheerd stelsel. Financiële overwegingen, in plaats van hydraulische behoeften, hebben het waterbeheer zoals uitgeoefend door de gebruikers beïnvloedt. Het gebruik van de pompen wordt geminimaliseerd met het oog op de hoge kosten die daarmee gemoeid zijn. In dat licht bezien moeten de behaalde resultaten worden beoordeeld. De proportionele waterverdeling, die wordt bewerkstelligd door het gebruik van fayoum verdeelwerkjes, functioneert goed, hetgeen kan worden afgeleid uit de simultane verbouw van gewassen door de verschillende boerengroepen. Toch blijft de noodzaak aanwezig om te komen tot transparante boeren organisaties die hun leden aanmoedigen betalingen te doen voor het onderhoud van kanalen, wegen en omheining van het stelsel. Voor het bewerkstelligen van een stabiele watervoorziening op de langere termijn dient men te overwegen een kanalenstelsel aan te leggen dat het systeem in directe verbinding stelt met de water reservoirs in Ruti, Rusape en Osborne. De voordelen van zo’n verbinding liggen in het reduceren of zelfs elimineren van het gebruik en de kosten van het gebruik van pompen, een verbeterde beheersing van de verzandingsproblematiek en overstromingsgevaar veroorzaakt door de Save rivier, alsmede in de mogelijkheid gecombineerd gebruik te maken van putwater en oppervlaktewater om de betrouwbaarheid van watervoorziening in kleinschalige irrigatie te vergroten.

Hoofdstuk 7 en 8 behandelen irrigatiestelsels die zijn geoutilleerd met de meest recente technologiën die uit het technologisch traject in Zimbabwe zijn voortgesproten. Het betreft hier gesloten sproei irrigatiesystemen. Het Bonde stelsel, dat wordt behandeld in **hoofdstuk 7**, bevat verschillende innovatieve componenten die het product zijn van dit technologische traject. Het stelsel maakt gebruik van hoge druk die een flexibele bedrijfsvoering mogelijk maakt. Verder is het stelsel uitgerust met dubbele pompen (voor het gehele stelsel en voor ieder geïrrigeerd blok), is het stelsel grootschalig naar Zimbabwaanse maatstaven, en wordt het beheerd door de boeren zelf. Echter in de praktijk zijn de behoeften van het systeem en de daarvoor benodigde aansturing slecht doordacht. De ontwerpers zijn uitgegaan van de veronderstelling dat na aanleg van het systeem de boeren spontaan een beheersstructuur in het leven zouden roepen die een hoge mate van water-toediening efficiëntie tot doel had. Verondersteld werd dat de boeren dit zouden kunnen doen door het effectueren van een combinatie van collectieve programmering van watervoorziening op basis van de behoeftes van de gewassen, waarbij de keuze voor een gewas aan het individu werd overgelaten. De electriciteitskosten werden hierbij onvoldoende in beschouwing genomen. Een analyse van de problemen van het stelsel heeft naar voren gebracht dat de selectie van de pompen gebrekkig is verlopen. Er zijn verscheidene fouten in het ontwerp geslopen die te maken hebben met de capaciteit om verzilting aan te pakken, pompen te repareren en voldoende middelen te mobiliseren om de electriciteitsrekening te kunnen betalen. Nieuwe gebruikers van het stelsel hebben onderschat hoeveel arbeid en doorzettingsvermogen benodigd is om de 'verzandings-oorlog' bij het pomphuis te kunnen voeren. De gebrekkige betrouwbaarheid van de watervoorziening – voornamelijk veroorzaakt door het falen of zelfs sluiten van de pompen – is één van de grootste zorgen van de boeren in Bonde gebleven, ondanks de verbetering van de watervoorziening in de rivier als gevolg van het gebruik van water uit de Ruti dam. Dit laatste is iets waar het Deure stelsel wel van heeft kunnen profiteren. Als mogelijkheid om de werking van het stelsel te verbeteren propageren de lokale gebruikers de aanleg van een stuw en toevoerkanaal in de rivier om aldus het huidige gebruik van pompen te elimineren. Deze optie beschouw ik als een duidelijke ingang voor een op te starten leerproces dat gebruik maakt van lokaal aanwezige kennis en institutioneel geheugen. Ontwerpers dienen zich te realiseren dat boeren en lokale organisaties tijd nodig hebben om de lokale situatie te doorzien om vervolgens hun eigen capaciteiten te ontwikkelen door het ondernemen van activiteiten die men aankan.

De evenredige toediening van irrigatiewater vormt waarschijnlijk het grootste voordeel dat kan worden behaald met het gebruik van moderne, gesloten sproei irrigatiesystemen. Helaas, blijkt in **hoofdstuk 8** dat de praktijk vaak weerbarstiger is dan de theorie. De resultaten die worden behaald met een 'draghose' sproeisysteem in Mpudzi blijken teleurstellend, ondanks het feit dat met behulp van de aanwezige zwaartekracht geïrrigeerd kan worden en er dus geen energiekosten gemoeid zijn met het functioneren van het systeem. Het gehanteerde onderhoudsbeleid en de wind gooien echter roet in het eten. Om nachtirrigatie en negatieve effecten van wind te voorkomen gebruiken de boeren grotere sproeikoppen en waterslangen, hetgeen resulteert in een lagere waterdruk op het systeem. Om waterschaarste het hoofd te bieden worden er vergaderingen en onderhandelingen in Mpudzi georganiseerd die een zelfde aard hebben als in de andere stelsels en hetgeen resulteert in verschillende hydraulische eenheden die om de beurt irrigeren. Het laagst gelegen blok in Mpudzi is uitgerust met een modern technologisch systeem en betrouwbare watervoorziening. Ondanks het ontbreken van organisatorische problemen slaagt dit deel van the stelsel er niet in productief te worden aangezien het is gesitueerd op arme, zandige gronden.

Er is een gebrek aan organisatievermogen dat de gebruikers kunnen hanteren om het geraffineerde systeem te onderhouden. De uniforme toediening van irrigatiewater behelst een complexe operatie die bovendien niet van direct belang is voor het produceren van gewassen. Het geraffineerde antwoord op de problematiek van onevenredige toediening van water op veld niveau laat zich niet oplossen zonder de aanwending van diepgaande studie en expertise. Het is hoog tijd de overdracht van het beheer aan de boeren kritisch te evalueren en te bezien welke taken centraal beheerd moeten worden, en welke zaken kunnen worden overgelaten aan privé ondernemingen en boeren. Het voordeel dat het systeem biedt op het vlak van flexibel, individueel gebruik resulteert niet in het noodzakelijke individueel georganiseerde onderhoud van de verschillende componenten van het systeem.

In **Hoofdstuk 9** worden de beheers- en onderhouds-praktijken samen met de lokale waterbeheer strategiëen vergeleken. Er bestaat een grote diversiteit met weinig gestandaardiseerde praktijken onder de verschillende systemen, hetgeen vragen oproept met betrekking tot de gehanteerde ontwerp- en overdrachts-procedures. Ook wordt aangetoond dat boeren en lokale actoren eigen processen initiëren om de problemen te lijf te gaan. Manzungu's (1999) stelling dat waterbeheer op veld niveau wordt gekenmerkt door ad hoc praktijken en niet door wetenschappelijk onderbouwde water planning wordt door deze studie bevestigd voor zowel oppervlakte water systemen als sproei systemen. Een andere bevinding van deze studie is dat de keuze voor een gewas niet alleen wordt bepaald door markt en levensonderhoud overwegingen (Rukuni 1994), maar evenzeer worden beïnvloed door de betrouwbaarheid van de watervoorziening. Boeren besteden veel aandacht aan de planning van het groeiseizoen, en doen dat in toenemende mate in geval van een terugtrekkende overheid (of die terugtrekking nu gepland is of bij verstek geschiedt). Daar waar de eenvoud van het watervoorzieningssysteem het toelaat eigenen de boeren zich het waterbeheer uiteindelijk toe.

Daar waar de technologie een hoge mate van raffinement vertoont, pogen boeren allereerst het systeem te vereenvoudigen en aan te passen op lokale omstandigheden door het inschakelen van lokaal aanwezige expertise voor de reparatie en het onderhoud van de werken. Dit proces van lokale aanpassing (localisation) behelst ook het minimaliseren van onderhoudskosten door het vervangen van onderdelen met lokaal beschikbare of gemakkelijk te gebruiken materialen. Indien deze methode faalt treden de boeren in diepgaand overleg met de overheid of andere dienstverlenende instanties waarbij zij hun verwachtingen ten aanzien van de water voorziening expliciet maken. Als dat ook geen bevredigende uitkomsten oplevert begint de cruciale fase van het herontwerpen van de werken. Dit laatste behelst een proces waarbij de boeren hun gewasprogramma's aanpassen, het geïrrigeerde areaal reduceren en – waar dit niet mogelijk is – uit de geïrrigeerde landbouw treden om regenafhankelijke landbouw te gaan bedrijven binnen dan wel buiten het stelsel.

Deze studie toont aan dat de overheid zich weinig moeite heeft getroost om enigerlei vorm van klantvriendelijke relatie te bevorderen tussen de irrigatie-industrie en kleinschalige boeren die gebruik maken van geraffineerde irrigatiesystemen. Er is ook een zekere terughoudendheid bij de boeren om financiële middelen ter beschikking te stellen voor de aanschaf van de benodigde kennis en reserveonderdelen voor hun technologisch verfijnde stelsels. Een oorzaak hiervoor ligt in de verwarring die bestaat rondom het bezit van de technologie. Verder zien de boeren weinig heil in het investeren in efficiënte methodes van water toediening op veld niveau, indien het water dat aldus wordt bespaard later terugstroomt in de rivier.

Deze studie toont aan dat boeren liever niet betalen voor water en onderhoud tenzij daar een dienst tegenover wordt gesteld, en een winstgevende nering resulteert die de gemoeide kosten dekt. Indien nodig, verdelen boeren schaars water volgens evenredige tijdsdelen, liever dan volgens gemeten water hoeveelheden. De behaalde resultaten per systeem tonen dat de technologie *an sich* geen verschil produceert in de efficiëntie van het watergebruik. De studie naar behaalde resultaten per systeem heeft eerder het karakter aangenomen van een studie naar de belangwekkende, innovatieve en soms exploitatieve aard van activiteiten ondernomen door boeren en veldwerkers om de watervoorziening aan de praat te krijgen.

In het concluderende **hoofdstuk 10** wordt een oproep gedaan aan de irrigatie ontwerp- en beheers-instanties in Zimbabwe om hun technische grondregels te herzien en het technologische traject om te buigen. Het is hoog tijd om doelstelling, functionaliteit en terotechnologie opnieuw te definiëren middels een proces van consensus en onderhandeling, gebaseerd op een grondige probleem stelling, analyse en optimalisering van relaties. Het is noodzakelijk te komen tot overeenstemming over de veranderings-strategiën die gebruikers willen en kunnen nastreven in het waterbeheer.

Een breder perspectief is noodzakelijk voor het ontwerp van toekomstige kleinschalige irrigatiestelsels. Boeren en lokale actoren hebben belang bij een betrouwbare watervoorziening, nieuw ontworpen systemen die zich lenen voor lokaal onderhoud, duidelijke afspraken over het bezit van infrastructurele werken, en een heldere regulering en beheer van systemen. Het is hierbij noodzakelijk realistisch te zijn over de mogelijkheden voor boeren beheer dan wel gezamenlijk beheer. Deze studie stelt voor de twee overdracht benaderingen die momenteel in zwang zijn – dienstverlening door het bedrijfsleven en infrastructureel beheer door semi-overheids instellingen – simultaan te proberen, met voldoende oog voor lokale configuraties van instanties, en op gefaseerde wijze. Ook is het noodzakelijk de juiste openbare voorzieningen te treffen, alsmede regulerende en bestuurlijke structuren te vestigen op legale basis, en te zorgen dat dezen verantwoording verschuldigd zijn aan alle leden zodat financiële transparantie en openbaar toezicht gegarandeerd zijn. Dat laatste zal de groei en duurzaamheid van de sector in grote mate bepalen. Het is een zaak van hoge urgentie om de daarvoor benodigde beleids- en toezicht houdende instanties in het leven te roepen.

Het blijft noodzakelijk de capaciteit van boeren om te anticiperen en toezicht te houden op waterverbruik te verhogen, zodat ze betekenisvolle partners kunnen worden in het water planning en consultatie proces, zoals dat momenteel wordt beoogd in het nationaal strategisch plan voor waterbeheer (WRMS) middels interactieve betrokkenheid van de gebruikers. Dit zal wellicht de capaciteit van boeren verhogen om nieuwe technologiën te gebruiken en nieuwe systemen te beheren die voldoen aan een vernieuwde vraag om water. Echter, dit zal niet gebeuren wanneer boeren wantrouwig blijven ten aanzien van toezicht en water metingen als technieken om hun toegang tot water te onthouden. Wederzijdse discussie over nieuwe technieken voor het taxeren van infrastructurele werken en onderhoud van de watervoorziening kan ook van nut zijn om terotechnologie te creëren rond nieuwe associaties met een openbare, privé en burgerlijke aard.

Irrigatie ingenieurs in Zimbabwe dienen mensen te zijn die geïnteresseerd zijn in, en begrijpen, hoe irrigatie systemen werken, en niet enkel weten hoe ze een systeem moeten ontwerpen en aanleggen. Zimbabwe heeft behoefte aan technische grondslagen die bijdragen aan het ontstaan van robuuste, duurzame en betrouwbare systemen voor kleinschalige boeren, en niet enkel bijdragen aan het individualiseren van water gebruik.

CurriculumVitae EE Chidenga

Eric Eria Chidenga was born in 1963 in Mwanza village, in Goromonzi District, in Zimbabwe. He attended the village primary school and completed his secondary education at Makumbi and Goromonzi secondary schools. In 1985 he attained a BSc degree in Agriculture (soil science) at the University of Zimbabwe. He then joined the irrigation branch of Agritex in 1986 and worked as an irrigation specialist. He obtained an MSc degree in irrigation at Newcastle Upon Tyne in 1989. From 1987 to 1993 he worked as a provincial irrigation specialist in Manicaland, before returning to Harare to head the irrigation branch. In 1998 he enrolled at Wageningen University for the “sandwich” PhD study, under the ZIMWESI II program and completed his fieldwork in 2000. In 2001 he was briefly appointed head of the Soil Conservation Branch of Agritex before transferring to the new irrigation unit under the Ministry of Rural Resources and Water Development.