Small-Scale Irrigation — A Foundation for Rural Growth in Zimbabwe

Report of the Zimbabwe Joint Field Workshop

Water Management Synthesis Project

WMS Report 66

SMALL-SCALE IRRIGATION --
A FOUNDATION FOR RURAL GROWTH IN ZIMBABWE

Report of the
Zimbabwe Joint Field Workshop

Prepared by

Zimbabwe Joint Workshop Team

WMS Report 66

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I. EXECUTIVE SUMMARY

A. INTRODUCTION

Successful small-scale irrigation can provide employment and generate income in rural areas. Consequently, small-scale irrigation can provide a foundation for rural development and growth. In Zimbabwe, small-scale irrigation (or smallholder irrigation, as it is frequently referred to) is distinguished from commercial or estate irrigation enterprises. The Zimbabwe Joint Field Workshop (JFW) investigated a range of small-scale irrigation schemes. The results of the workshop, with findings and recommendations for action, are reported here.

The Joint Field Workshop (JFW) was held in Zimbabwe from January 19 to February 28, 1987, as part of the USAID Africa Bureau initiative in irrigation. The Joint Field Workshop was funded by USAID and was held in cooperation with the University of Zimbabwe and AGRITEX, the extension division of the Ministry of Agriculture.

B. OBJECTIVES

The overall objective of the Joint Field Workshop was to develop an understanding of small-scale irrigation in Zimbabwe with respect to the interdisciplinary aspects of agronomy, engineering, economics, and sociology, and with specific emphasis on the potential for and constraints to further development. The investigation used an interdisciplinary team of U.S. and Zimbabwean counterparts to develop systematic, field-based information related to the irrigation process, and to develop recommendations for further development.

The specific objectives were:

1. Develop an integrated interdisciplinary team of U.S. and Zimbabwean counterparts.

2. Acquaint the U.S. component with Zimbabwean conditions and the Zimbabwean component with socio-technical analysis of irrigation systems.

3. Perform team field studies on selected sites to develop information on the current operating conditions of the irrigation systems studied.

4. Analyze, integrate, and synthesize the information obtained, together with other available data, to provide insights into the processes and constraints of small-scale irrigation in Zimbabwe, and to provide recommendations for further development.

5. Prepare a report and present the findings to USAID and Zimbabwean officials.

In addition, the following statement was added to the original statement of objectives and scope to ensure understanding of the joint nature of the Joint Field Workshop: It is understood that all phases of activity of the [Joint Field Workshop] will be undertaken as fully joint and equal from initial orientation to field work to development of recommendations to preparation of the final report. The cooperation and input of the Zimbabwean counterparts are vital to the success of the [Joint Field Workshop].

C. METHODOLOGY OF THE JOINT FIELD WORKSHOP

The Joint Field Workshop was organized using the principles developed for diagnostic analysis (Podmore, 1983), and the diagnostic analysis literature was used as a resource for the activity. Use was also made of the Nepal rapid appraisal (Laitos et al., 1986) in order to demonstrate the application of rapid appraisal techniques.

The rapid appraisal technique makes use of the concept of "optimum ignorance" (Laitos et al., 1986). The understanding that can be obtained of a small-scale irrigation scheme in a short time (5-7 days) is imperfect. The ability of the team to read and absorb existing information, collect data, and identify constraints is limited. Consequently, agreement must be reached on an appropriate level of imperfection for the study. Discussion between team members, and the overall purpose of the study, limit the selection of the level of "optimum ignorance." In interpreting the results of the study, it is important to keep this in mind.

The joint U.S.-Zimbabwean interdisciplinary team consisted of agronomists, engineers, economists, and sociologists. A disadvantage of the team composition was that it was not possible to include a Zimbabwean sociologist. The team was cross-organizational since it included representatives from U.S. and Zimbabwean universities, the Zimbabwean extension service (AGRITEX), a parastatal (ARDA), and private consultants.

The sites investigated during the Joint Field Workshop were selected based on existing information (GOZ, 1985; Podmore et al., 1986) in consultation with Zimbabwean personnel. The selection of the sites was an attempt to obtain as broad a cross-section of the small-scale irrigation sector as possible within a limited number of sites. The site selection criteria included region of the country, size of irrigated area, topography, soils, crops grown, source of water and its application (i.e., gravity diversion, pumped from weir or groundwater), method of irrigation, availability of inputs, market conditions, and system organization. It was recognized that, with only four sites and a wide range of conditions, no site could be considered typical, and no attempt was made at statistical representation.

The Joint Field Workshop was divided into three sections as follows.

Orientation (1 week - held in Harare). The activities included presentations on Zimbabwean conditions, the selected sites, and rapid appraisal techniques; development of a draft report format for each scheme; and team building activities. The report outline was as follows:

A. Introduction
B. Physical System
C. Social/Institutional System
D. Characteristics and Performance of System Management
E. Characteristics of the Agricultural System
F. Financial and Economic Performance
G. System Strengths and Weaknesses

Site Investigations (4 weeks - at field sites). The activities included reconnaissance of the scheme, interviewing key personnel, developing a workplan for the time available, collecting the required data, holding team meetings to plan logistics and discuss findings, and developing a draft report for the scheme.

Conclusion (1 week - held in Harare). The activities included reviewing the scheme reports; developing overall findings, conclusions and recommendations; producing a draft final report; holding debriefing sessions for USAID and Zimbabwean senior officials; and conducting evaluations of the workshop.

D. SITE DESCRIPTIONS

The sites were chosen to illustrate the range of conditions in small-scale irrigation in Zimbabwe. The sites are presented in the order in which they were investigated.

1. Tsovane

This scheme is one of the few that have been built since independence. Tsovane scheme started operating in 1985. It is operated by the Agricultural and Rural Development Authority (ARDA) as an estate with a small settler area. The total area is 338 ha, with 68 ha under settler control. Each settler family has a 2-ha holding, and there is an ambitious plan to gradually hand the scheme over to the settlers over a period of eight years.

The water supply is pumped from the Save River into night storage dams for distribution via canals. Two predominant soil types are present which affect irrigation scheduling and water conveyance. Canals through coarse-textured soils were lined, whereas no lining was installed on the clayey soils. The main crops were cotton and wheat. Yields were high (3,000 kg/ha and 4 t/ha, respectively), and returns to farmers were above average.

The scheme has very good management, and the farmers have an irrigation committee which interacts well with the settlement officer and scheme manager.

2. Mutema

Mutema scheme is operated by AGRITEX and has a scheme manager and an irrigation committee. The extension service is good, with a relatively high ratio of extension workers to farmers (1:80).

Mutema scheme has an area of 237 ha, of which 183 ha are sprinkler-irrigated and the remainder are surface-irrigated. Water for surface irrigation is diverted from the Tanganda River, which carries a high sediment load. Seepage losses from the supply canal are high. The surface irrigation is little more than controlled wild flooding, and the efficiency of water use is low.

The sprinkler-irrigated area is on sandy soils and is supplied with groundwater by four pumps. One of the pumps has been inoperative for over a year for lack of a bearing. The sprinkler system was installed in 1973 and began to experience problems three years later. There has been little replacement of components, and the system is almost inoperative.

The landholdings are generally less than 1 ha. The main crops are maize, cotton, tomatoes, and beans, and yields are low. Farmer morale is poor.

3. Mutambara

Mutambara is one of the oldest schemes in the country, having been started in 1912. It is community-operated with no government input and little extension service. Water is diverted from the Umvumvumvu and Ruwako rivers and distributed through an extensive series of channels, within which seepage losses are high. Water is rotated from block to block, but there are considerable discrepancies in block area and water distribution is very nonuniform.

The Mutambara scheme has an area of 152 ha, and most of the landholdings are 1 ha or less. There is an irrigation committee with two elected representatives from each of the six blocks. However, the chief is the major figure on the scheme, and nothing happens without his approval.

The cropping pattern is maize followed by wheat or tomatoes. However, marketing problems have limited the returns from the tomatoes in the past. Fertilizer use is low, and this is reflected in lower than average yields.

4. Ngondoma

Ngondoma has an area of 22 ha and an excessive water supply from a dam which was built for a now inoperative gold mine. The scheme is operated by AGRITEX and managed by an extension worker. The cropping pattern has been modified to take advantage of early market conditions. With the security of adequate water, maize is planted early and harvested as green maize for the Christmas market. Okra is also grown. Tomatoes are planted early and command a high price, although transport is a problem. The scheme is well run, and there is a functioning irrigation management committee (IMC).

E. FINDINGS

The findings of the Joint Field Workshop are summarized below. Note that the findings are not mutually exclusive; where problems arise, they are frequently in combination.

1. Technical and Financial Analysis of Alternatives

Scheme Objectives. It was not possible for the team to establish the objectives for each scheme studied, except for the newly completed Tsovane, because there were frequent conflicts between the apparent objectives of each scheme. Schemes were said to have agricultural productivity as the objective, but food security and provision of rural employment were also given as objectives in the same scheme. While it is recognized that a scheme may reasonably have more than one stated objective, it is important to avoid conflict between the objectives. Conflict arises because meeting the objective of agricultural productivity (for example, acceptable farm family incomes and adequate payment capacity per plot) usually requires relatively large plots, while providing rural employment requires smaller plots so that more farmers can settle in a given area.

Changes in government priorities have occurred over the sometimes considerable time that has elapsed since the schemes were established. Consequently, the current scheme objectives may substantially differ from those originally established. In addition, changes in the schemes themselves have occurred over time. The area irrigated may have been enlarged, the landholdings may have been subdivided due to inheritance, or, as in Mutema, the method of irrigation and the source of water have changed. These aspects made evaluating the effectiveness of the irrigation schemes extremely difficult.

Recommended Action: Scheme objectives need to be clearly established for new and existing schemes with regard to the specific scheme socio-economic and agro-ecological environments. Where conflicts occur, methods of resolution need to be determined so that schemes can be evaluated fairly and equally. Evaluation methods can then be applied to compare scheme performance. The data can then be evaluated so that lessons can be learned from successful schemes and applied to those not meeting their objectives. Scheme modifications may be required that make attaining the desired objectives more likely.

Site Evaluation. Soil variability was found to be an important aspect of site evaluation because systems were less effective if they did not account for it in design and management. In the systems that were examined, soil variability had been incorporated into the design of Tsovane only, where canal lining and irrigation scheduling were modified to accommodate differences in the soil. For other schemes, particularly Mutema and Mutambara which were established before the importance of soil variability was fully appreciated, considerable problems resulted from not being able to incorporate soil variability into the design of the systems.

Recommended Action: When planning to rehabilitate an existing scheme or to construct a new scheme, a detailed soil survey to determine the area's suitability for irrigation is required. The survey should be used to plan the irrigation scheme and to lay out the areas to be irrigated. Although the JFW team was informed that this was the normal practice, it was indicated that the soil survey was sometimes done after the scheme was designed. Note that in the case of rehabilitation, reallocating land to farmers whose land has been eliminated from the irrigated area due to unsuitable soils is a real and serious problem. This problem would undoubtedly occur at Mutambara should a rehabilitation of the scheme be undertaken.

Cost of Doing Nothing. It was found that there was a general lack of appreciation for the costs, or opportunities not realized, when problems are left unsolved. For example, the expansion at Ngondoma, for which materials and supplies were on site, had been delayed for two years. The production foregone during that time was estimated at $80,000/year.[1]

Recommended Action: When investigating proposed rehabilitation or expansion of existing schemes, the cost of delay should be considered. It is necessary to establish the value of water in order to estimate the cost of delay; the reports on the sites investigated (following this chapter) illustrate the procedure. Once the cost of delay is determined, alternative or partial solutions can be evaluated to estimate their contribution to offsetting the loss of revenue.

Least Cost Options. The expansion of Ngondoma was estimated, from GKW designs (GOZ, 1985), to cost $300,000, or $18,750/ha; while implementing the much more complex scheme at Tsovane cost just over $10,000/ha. The lack of available funds from the government to implement the $300,000 design caused the delay referred to above. It seems likely that a less costly design alternative could have been developed for Ngondoma. In addition, alternatives which involved the use of local resources and/or a willingness to implement a partial expansion would have required far fewer government funds. An active search for least cost and financially feasible alternatives would probably have yielded options which were both feasible and more attractive in economic terms.

Recommended Action: The consideration of least cost options can be coupled with cost of delay considerations to establish appropriate courses of action. The economic and financial analyses performed by the team indicate that few schemes can support high investment costs per unit area. Consequently, careful analysis of options needs to be

[1]All dollars in this report are Zimbabwe dollars.

undertaken in order to develop least cost options for irrigation development.

Recurrent Costs. The sprinkler system at Mutema and the surface irrigation system at Mutambara need rehabilitation. Least cost options, as indicated above, should be investigated. However, it is also necessary to estimate the recurrent costs for the rehabilitated systems. Recurrent costs for a rehabilitated scheme represent the ongoing cost of doing business. The deterioration of the sprinkler system at Mutema is an example of the consequences of not providing sufficient funds to meet recurrent costs.

Recommended Action: Estimating recurrent costs will indicate the financial liability of the agency responsible for system maintenance. For example, recurrent costs for the sprinkler section of Mutema could be estimated from data from the nearby Middle Save estate. If production levels are to be maintained, recurrent costs must be met through payment capacity generated from the scheme or from funds from other sources. If the payment capacity is to be generated from the scheme, productivity and plot size must be such that the objectives of acceptable farm family income and payment capacity per plot can be met. A scheme must generate enough revenue to provide the farmers with sufficient income and to meet recurrent costs. Mechanisms need to be set up to recoup this revenue and use it to maintain the system. Not only is it advisable for this to be done to keep the system operating, but farmers should see it done. This way, farmers will realize that their money is being used to their benefit, and they will help to maintain the system and offset repair costs.

Productivity and Water Supply. Where water was available in adequate quantities and the supply was reliably and equitably distributed, productivity -- as measured by gross margins -- was high. These conditions were met at the Tsovane and Ngondoma schemes, whereas the Mutema and Mutambara schemes showed problems in these areas. Unofficial expansion of irrigation schemes usually leads to degradation of the reliability and equity with which the available water supply can be distributed.

Recommended Action: According to the team's findings, a necessary condition for a productive scheme is the availability of a reliable and adequate water supply which can be equitably distributed. When considering new or expanded schemes, this aspect must have high priority. On existing schemes, modifications may be necessary so that the reliability and adequacy of the water supply can be increased. If these changes are required, but not possible, then reduced productivity for the scheme must be accepted. As a result, modifying scheme objectives may be necessary.

2. Education and Training

Farmers. Generally good extension programs were found for farmers, and AGRITEX is to be commended for their efforts. However, programs in irrigation were found variable in quality and quantity, and not existing in some cases. The situation at Tsovane was an exception, since in-service training was given to the future farmers before they took over their holdings. Farmer interest in irrigation was high, and they were receptive to training programs.

Training for the irrigation management committee was viewed as creating an arm of government, since the irrigation management committee often collected irrigation fees. An additional problem was turnover in IMC membership, which tended to dissipate the results of training. IMC training should also deal with problems related to handing schemes from government to local management, since this is current government policy.

Recommended Action: Develop and expand the irrigation extension program, including providing service to community-managed schemes. Ongoing training programs for irrigation committee members is necessary to maintain standards for committee performance. If government policy of handing schemes over to the farmers is to be effective, training must include encouraging committee members to accept responsibility for their schemes.

Extension Workers. Considerable variation in extension service to the schemes investigated was noted, and service to the communal scheme of Mutambara was particularly poor. In spite of this, extension workers were almost without exception highly motivated personnel who would gain significant benefit from further irrigation training. In addition, the team perceived a need for training in collecting farm management data in order to establish a firm data base for future recommendations.

Recommended Action: Existing irrigation curricula in agricultural colleges should be strengthened, and in-service training programs in irrigation for extension workers should be expanded and made more readily available. Data collection and recording procedures should also be included. In addition, an investigation of overall extension to small-scale irrigation schemes is recommended, with the goal of improving service.

Agency Personnel. With reference to the government policy of handing over irrigation schemes to local farmer control, there appears to be a lack of appreciation on the part of government agency personnel of the conditions and issues involved.

Recommended Action: Consideration should be given to instituting in-service training programs for government agency personnel, including material on organizational concerns and scheme management issues.

Management. At the schemes where a "scheme manager" was present and effective, as at Tsovane and Ngondoma, management levels were high, the supply of inputs was more assured, and markets were utilized for disposal of crops. At Tsovane scheme, management was more structured since ARDA was instrumental in supplying inputs and the marketing boards were the receiving agencies for the crops. At Ngondoma, the input suppliers and markets were more informal, but none the less successful.

At Mutema, a scheme manager was present, but the level of management was lower since he was not was not required, under AGRITEX guidelines, to expedite input supplies nor influence marketing. A recent experience with a tomato crop caused him to withdraw from involvement in marketing. At Mutambara no one functioned as a scheme manager. Consequently, the supply of inputs and the provisions for marketing were haphazard. Informal groups were occasionally formed to market crops cooperatively.

Recommended Action: Effective management, including expediting input supplies and marketing processes, is necessary to ensure the success of a scheme. On schemes that will continue to be government-operated, adequately trained managers are required. AGRITEX should consider the role of the scheme manager in assisting with timely provision of inputs and marketing opportunities. On communal schemes, training irrigation committee members is necessary so that they can fulfill managerial functions. Alternatively, the scheme could hire a manager to run the scheme, but revenue generation would be required to implement this option.

Senior Officials. Within the context of the Joint Field Workshop there was limited contact with senior irrigation officials, which was anticipated within the structure of the Joint Field Workshop. However, that contact was very positive and supportive of JFW efforts. From experience elsewhere, it is extremely important to involve senior officials in the process of irrigation improvement and development.

Recommended Action: There is a need to develop a program, not just for personnel in the Ministry of Lands, Agriculture, and Rural Resettlement but also for personnel in the Ministry of Energy and Water Resources Development; the Ministry of Finance, Economic Planning, and Development; and in other related organizations. The content should sensitize participants to the issues involved and should include the senior officials in developing a plan for implementing small-scale irrigation development.

Irrigation Professionals. Currently there are too few capable people in irrigation in Zimbabwe. The limited pool of expertise is vulnerable to a "drain" to the private sector where conditions of employment are more favorable. To counter this, the supply of fully qualified irrigation specialists should be increased.

Recommended Action: Support is needed for the irrigation program at the University of Zimbabwe to provide basic education in irrigation topics and to expand opportunities for short-term training courses overseas. Specific numerical objectives for irrigation professionals should be instituted to enable funding to be allocated.

3. Research and Administrative Studies

Agronomic. There is a need to gather water management data of all types including water requirements for current and alternative crops and crop coefficients. Information on soils management for irrigation is also needed. Where information does exist, it is not well-disseminated.

Recommended Action: On-going research programs are needed to gather the above information, especially on an interdisciplinary basis. Programs to collect and disseminate information must be strengthened.

Engineering. There is a lack of basic equipment for obtaining field measurements. Zimbabwe needs water management data, especially for controlling, measuring, and distributing irrigation water. In addition, the implications of applying "high tech" systems in a developing country, particularly in regard to reliability, need to be more fully investigated. An example of the misapplication of technology was the use of a sprinkler system at Mutema. The system encountered problems only three years after installation in 1973 and was badly in need of renovation. Maintenance of this type of irrigation system is essential.

Recommended Action: Programs to address the issues cited above are required, especially on an interdisciplinary basis. Evaluation of alternative irrigation methods and irrigation project management techniques should be incorporated into on-going research programs of an interdisciplinary nature. Information on system maintenance and the impact of technology should be included. A support program to provide necessary equipment is essential.

Institutional/Organizational Issues. There is a shortage of qualified people in the area of institutional and organizational issues and an apparent lack of research. If research exists and is on-going, then there appears to be a dissemination problem, since the team experienced difficulty in locating appropriate studies. Note that there is a strong existing tradition of "working together" in informal, cooperative organizations.

Recommended Action: Educational programs in institutional and organizational studies need to be enhanced. Action research programs with cooperating agencies are needed to investigate the forms of organization, and the potential of indigenous informal organizations without destroying them.

Interdisciplinary Scheme Studies. Interdisciplinary studies like the diagnostic analysis or rapid appraisal used here have been shown to be viable approaches for investigating irrigation systems. The reports on the schemes studied indicated the type of information that can be generated in a short time. An ongoing effort in training and in executing these studies would create a data base which would be extremely valuable in evaluating system performance.

Recommended Action: It is recommended that a Zimbabwean interdisciplinary team be formed to investigate one or more irrigation schemes with other representatives from AGRITEX, ARDA, and the University of Zimbabwe for training and to collect data. This action should be viewed as an initial effort in establishing a long-term program in evaluating and enhancing irrigation system performance.

4. Farmer Involvement and Organizational Structure

Irrigation Management Committees and Water Users Associations. Note that a water users association (WUA) is a subgroup of the irrigation management committee. At Ngondoma, WUAs were successful[2]; whereas on Mutambara, a communal scheme with a block structure, WUAs were absent. The team found that IMCs, where they existed and were effective, had considerable effect on scheme performance.

Recommended Action: Efforts need to be made to establish IMCs and WUAs, and to strengthen them where they already exist. Clarifying objectives for IMCs and WUAs is important, particularly when planning, implementing, operating, and maintaining schemes.

Extension Workers and Agency Personnel. The extension workers and agency personnel whom the team met were aware of and sympathetic to the situation of the farmers. However, there was a lack of sensitivity to the potential of farmer organizations and their impact on the productivity of irrigation schemes.

Recommended Action: Educational programs discussing farmer organizations are needed for extension workers and agency personnel to develop an understanding of the interactions of farmer organizations and agency personnel.

Implementation and Linkages. There appears to be a good underlying philosophy for the need for linkages between organizations. However, there is a lack of follow-through in developing and implementing linkages. There is a need to talk with and listen to farmers before planning an irrigation scheme, to identify and select settlers for the scheme, and to incorporate these settlers into the planning and implementation processes.

Recommended Action: The use of an interdisciplinary team is recommended to be implemented as an effective way to find ways to build the linkages mentioned above.

Effectiveness. There is, on the part of farmers, a fear of failure of "new" methods of organization for irrigation systems. This fear promotes conservative approaches on organizational issues. There is a need to encourage organizational innovations in an environment that is free of a "failure" stigma in order to encourage the investigation of lessons learned.

Recommended Action: A program of organizational experimentation needs to be instituted so that new organizational structures adapted to Zimbabwean conditions can be tried.

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[2]At Ngondoma, the water users associations were called block groups.

5. Water Resources and Control

Reliability. The importance of a reliable water supply to scheme viability was illustrated by all the schemes investigated. For Mutambara, one of the oldest schemes in the country, a reliable, if variable, water supply from river diversion produced a durable system, even though water was unevenly distributed with high losses. For Ngondoma, the water supply was far in excess of requirements due to the closure of the gold mine for which the original dam had been built. The reliability and continuous availability of the water made it possible to modify cropping patterns to take advantage of high value crops such as okra and early tomatoes.

On the other hand, Tsovane is a new scheme which completely depends on pumped water from the Save River. While the reliability of water supply is currently high, the scheme is vulnerable to equipment failure in the future. Although the system is only two years old, the farmers who are to take control of the scheme are asking how they will be able to replace the pumps when they break down. At Mutema, it was observed that one of four pumps had been out of service for over a year because of bearing failure and lack of a replacement. Fortunately, this pump is the smallest of the pumps, but the others are vulnerable to the same condition with greater consequences.

Recommended Action: It is necessary to ensure reliability of water supply for new and existing schemes to make systems "robust." Given the current shortage of foreign currency in Zimbabwe, reliance on imported components and technology is not recommended. Maintenance of existing schemes will improve the reliability of water supply, but alterations may be necessary to ensure reliability in the long term. New schemes need to have water supply reliability built into them in order to ensure long-term viability.

Measurement and Recordkeeping. Adequate measurement structures and records at the scheme level were frequently absent. Thus, allocating water at the local and, in the broader context, at the regional and national levels is difficult or impossible.

Recommended Action: Where measurement devices and data collection procedures are in place, they need to be strengthened and maintained. Where they are absent, appropriate flow measurement devices need to be provided and recordkeeping procedures need to be instituted. Prescribed uses for data, rather than data becoming an end in itself, are required. Also, a manual on the methodology of interdisciplinary data collection, analysis, and exchange is needed.

Resource Conservation. Water supply and water quality aspects, conveyance losses, the misuse of water, and off-scheme water use concerns are national issues. Irrigation development must be integrated with resource conservation, and water conservation needs to include consideration of the value of water.

Recommended Action: Programs in resource conservation, especially for soil and water, need to be expanded and integrated in order to preserve productivity in the long term.

Allocation and Water Value. The Ministry of Agriculture's Irrigation Development Committee and the Hydrology Branch in the Ministry of Energy and Water Resources and Development maintain records on water allocation for irrigation at the national and regional levels. However, information at the local level on water allocation and the value of water for irrigation was not as available.

Recommended Action: There is a need to implement a study of water value in irrigation, especially with respect to the time of use and cost of storage. The use of water pricing as an incentive for conservation and wise use of water is an alternative that has succeeded in other situations. This report indicates the kind of information that can be generated and its value.

F. JFW TEAM COMPOSITION

The joint interdisciplinary team was selected based on representation from various disciplines and organizations in the U.S. and Zimbabwe, as indicated in discussions with WMS project personnel and the Africa Bureau of USAID. The disciplines represented in this interdisciplinary approach were agronomy, engineering, economics, and sociology.

It was not possible to include a Zimbabwean sociologist on the team. This proved to be a disadvantage for the U.S. sociologist, but cooperation from the other Zimbabwean team members overcame the difficulty to some extent.

The team consisted of the following professionals:

Max Donkor - Irrigation engineer and graduate student, Colorado State University

Tom Flack - Agronomist; private consultant, Fort Collins, CO

Seymour Gimani - Irrigation specialist, AGRITEX

Robby Laitos - Sociologist, Colorado State University

Ransam Mariga - Economist, AGRITEX

Dick McConnen - Economist, Montana State University, and Executive Project Director, WMSII

Isaac Moyo - Irrigation specialist, ARDA

Terry Podmore - Team leader and irrigation engineer, Colorado State University

Aidan Senzange - Irrigation engineer, University of Zimbabwe

Solomon Tembo - Agricultural engineer and local coordinator, University of Zimbabwe

Pangirai Tongoona - Agronomist, University of Zimbabwe

A last minute arrangement with USAID S&T (Energy) included two energy specialists on the team. Their mandate was to investigate energy availability and use in irrigated agriculture in Zimbabwe, with particular reference to energy for irrigation pumping. Due to the late addition of these members to the activity and to conflicts in their schedules, they were only able to interact with the team for a short time. The energy specialists were:

Peter Fraenkel	Alternative energy specialist I. T. Power, U.K.
Ron White	Energy economist; private consultant Austin, TX

The reports on energy availability and use in irrigated agriculture in Zimbabwe are given in Appendices B and C. The JFW team findings for the schemes studied are contained in the subsequent chapters.

II. TSOVANE IRRIGATION SCHEME

A. INTRODUCTION

Tsovane irrigation scheme is located on the west bank of the Save River immediately downstream of the confluence of the Save River and the Mkwasine River. Access is via a gravel road being upgraded to tarmac which turns off from the Ngundu-Tanganda Road some 52 km east of Chiredzi and 6 km west of the Jack Quinton Bridge over the Save River.

The scheme comprises 338 ha of irrigable land. Tsovane reached its present form under the Agricultural and Rural Development Authority (ARDA) in late 1984 and produced its first crop in 1985. Prior to that only about 20 ha were developed for irrigation for 35 farmers, and the scheme operated under the purview of the Ministry of Lands, Resettlement and Rural Development. A site plan is shown in Figure 1.

Of the 338 ha under irrigation, 68 ha are allocated to 34 settlers -- each farming 2 ha. The rest of the area is operated by the core estate, which is planned to be phased out over eight years in favor of more farmers who will be allocated the irrigation land.

The estate has 54 permanent employees and employs varying numbers of seasonal, casual, and contract laborers during the cropping seasons to pick cotton, weed fields, maintain canals, and spray crops. The settlers obtain input requirements like fertilizer and land preparation machinery through the core estate, but they hire their own labor for such activities as cotton-picking and hand-weeding.

An administrative and workshop complex is west of the North Block. The workers and farmers live in two villages on the scheme, and the estate manager's house is near the river pump station.

Farmers throughout this scheme practice furrow irrigation using siphons and spiles to apply the water from field canals. The cropping pattern for the entire Tsovane scheme is a standard rotation of cotton in summer and wheat in winter. A small area of sugar beans is also grown. Irrigation in summer is supplementary, while winter irrigation is full-time.

Some of the original objectives of this irrigation scheme are as follow:

1. Relieve land pressure in this area. Tsovane lies in a region that receives a mean annual rainfall of less than 500 mm, which makes dryland agriculture unsuitable except for livestock production.

2. Realize the full potential of the existing resources of water and land to benefit the local population, thereby raising their incomes and standard of living.

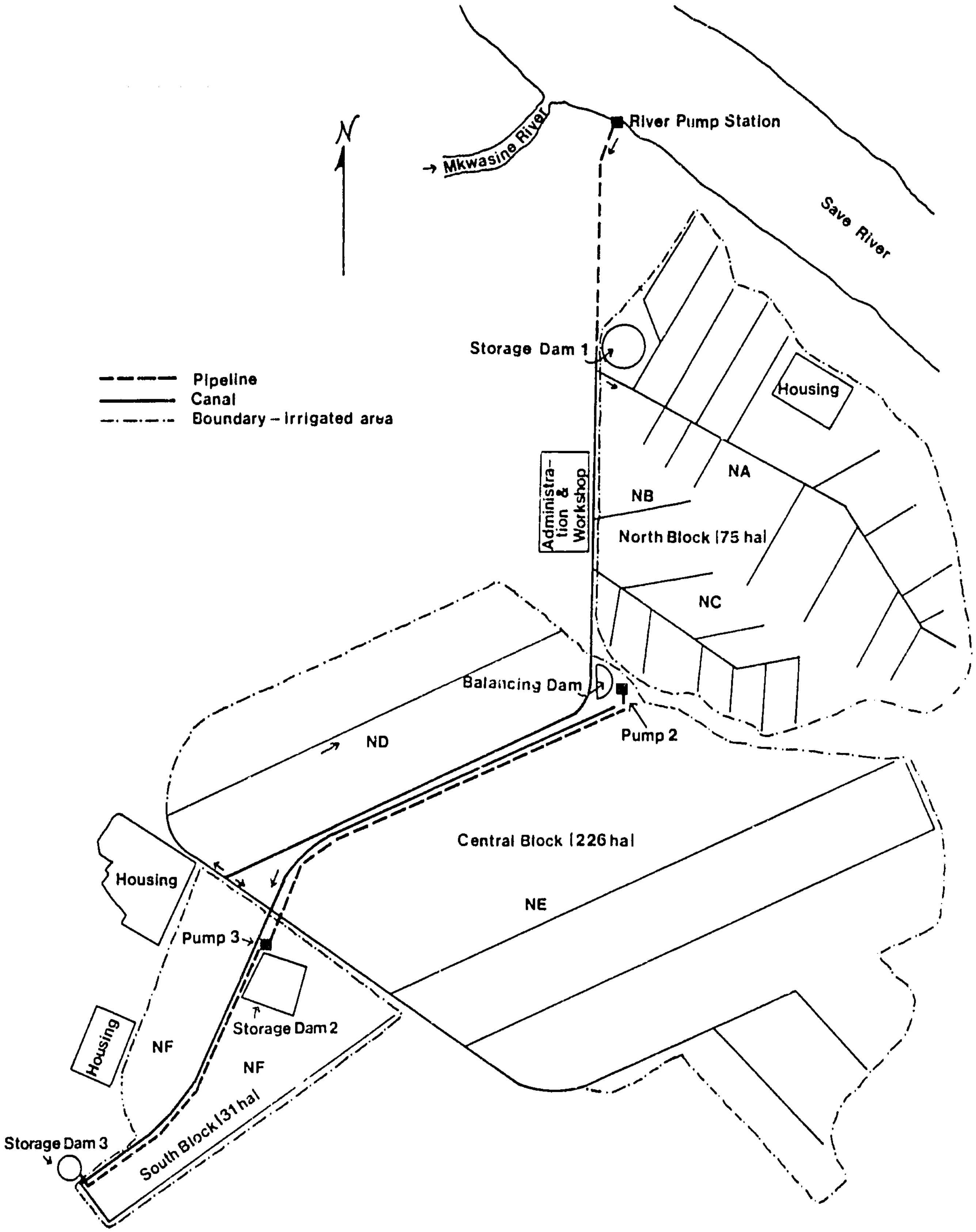


Figure 1. Tsovane site plan.

B. THE PHYSICAL SYSTEM

1. Climatic Data

The average annual precipitation at Tsovane is 500 mm with considerable variation in distribution and amount. Most of the precipitation comes from thunderstorms from November through March.

The average annual temperature is 22°C, although 37°C is not uncommon from October through February. Frosts are rare, but may occur in low-lying, wind-sheltered areas during the night. The average annual evaporation is 2,138 mm, and the average daily evaporation is 5.86 mm. The average relative humidity is 63 percent and the average daily sunshine is 8.3 hours.

2. Hydrology

Water Source. The Save River is the main source of water for the Tsovane scheme. In dry periods, the river flow is supplemented by releases from two dams upstream, the Ruti and the Rusape. The Ruti Dam is controlled by the Regional Water Authority, from whom those on the estate order their requirements. Special provisions exist for abstracting water from the Save riverbed in drought years.

The Save River exhibits large seasonal and perennial variations in flow. The 1-in-100-year flood level is estimated to be 9,000 m^3/s at an elevation of 378 m above sea level. In contrast, after two or three successively poor rainy seasons, surface flow can stop entirely. Yet, the water level in the sand of the riverbed after several years of drought is unlikely to fall below 370 m above sea level. In normal years the water level fluctuates between approximately 370.45 m and 372.45 m above sea level.

Water Supply. During periods of normal river flow (November-March), available water is estimated to be 756 m^3/h/pump. The total supply is obtained from the normal river flow at no cost for the water.

However, in the dry season (April-September), supplemental releases from the Ruti and Rusape dams are required. The estimated total water supply is requested from the Regional Water Authority two to three weeks in advance. These requests are then met through a combination of river flow and dam releases, taking into account losses along the river from the dams to the intake structure of the project.

In periods of normal river flow, a 6-day supply schedule is used for the three blocks of the estate (North, Central and South). Based on 12 hours of pumping using both pumps, normal water delivery is estimated at 108,864 m^3/week, with the peak delivery estimated at 127,008 m^3/week.

Catchment. The dimensions of the catchment area of the Save River were not available. A problem observed within the catchment is the high level of siltation. Silt content at Middle Save (approximately 18 km upstream) is estimated to be about 14 percent by the Ministry of Water Resources Development (MWRD). The high level of siltation has resulted in the need to build an elaborate intake structure to control the amount of silt pumped with the water to the scheme (ARDA, 1984).

Water Rights. According to the Water Act of 1976, the Ministry of Water Development holds the water rights for government irrigation schemes (AGRITEX, 1973).

The water right application for the Tsovane scheme was submitted after project completion. Due to the late submission, the scheme depended on Chisumbanje, another ARDA scheme, for water supply in the first two growing seasons. The Tsovane water right is 0.45 K cumec.

Theoretically, a water right entitles its holder to 1 L/s/ha/year of discharge from an adjacent river. This translates to 12,000 m^3/ha under normal river flow conditions.

Where structures (i.e., dams) have been built to ensure the exercise of this right, the costs are partially or wholly recovered through payment of user fees. At Tsovane, supplemental releases from the Ruti Dam are priced at $12/1000 m^3.

3. Soils

As classified by Verboom et al. (1981), approximately 15 percent of the irrigable area consists of Class A soils, which require no special practices to sustain long-term irrigation. About 60 percent of the irrigable area consists of Class B soils, mostly black Vertisols, which require special management due to minor topographic and soil deficiencies. The remaining area (25 percent) consists of Class C and D soils, which have severely restricted suitability for irrigation due to topography, shallow depth to bedrock, and poor drainage and/or sodicity.

Two main soil types make up the bulk of the irrigable area. The Class A soils are composed entirely of the so-called "red soils." This land occurs in the northern estate area, and the soils are characterized by reddish color, sandy loam surface layers, and sandy clay loam or sandy clay subsoils. They are deep soils derived from mafic rock and influenced by old alluvium.

Weathering has been intense, and the soil pH is typically acid (pH 5.0 to 6.0), with higher reaction below 1 m where calcium carbonate has accummulated (pH 6.5 to 7.5). Base saturation is above 80 percent, but the cation exchange capacity is low. Hence, these soils retain fertilizers, but applications should be split through the season.

The sandy clay loam textures pose no tillage problems. The infiltration rate is moderately rapid, permeability is moderate, and the available water capacity is moderate (10 percent, or 100 mm of water per meter of soil). The suggested irrigation cycle for these soils is seven days.

The Class B soils are composed mostly of the so-called "black Vertisols," or Pellusterts (USDA soil taxonomy). This land occurs in the central and southern estate areas and in most of the resettlement area. The soils are characterized by dark grey to black colors, clay textures (50 to 70 percent clay), and neutral soil reaction (pH 6.5 to 7.5). They are derived from basalt. Weathered bedrock commonly occurs at depths between 80 cm and 120 cm. Basalt fragments are often present near or on the soil surface, especially in the South block. Base saturation is above 90 percent, and the cation exchange capacity is high.

These soils are generally more fertile than red soils, but are more difficult to manage due to the high clay content. The high shrink-swell nature of these soils cause root pruning when very dry and aeration problems when wet. Infiltration is very slow, permeability is slow, and the available water capacity is high (18 percent or 180 mm of water per meter of soil). The suggested irrigation cycle for these soils is 14 days.

The remainder of the project area soils are mostly variations of these two major soils. Depth to bedrock poses the most restrictive limitation (50 cm). Shallow soils are dominant at the margins of the scheme, and soils with impeded drainage and sodic subsoils occur in drainageways and adjacent to the Save River. For the most part, they are poorly suited to irrigation, but have nonetheless been incorporated in the scheme.

4. The Physical System

Tsovane irrigation scheme is a pump-fed, gravity distribution system. Irrigation water is taken from the Save River through a groyne-type intake structure. The groyne intake projects into the river and, under normal conditions, takes the top 150 mm of water into the inlet by means of floating radial gates. When the water level in the Save River drops too low for the two radial gates, then an emergency gate at the end of the intake structure can be used.

Water from the intake flows southward through a 32-m long, 900-mm diameter conduit and enters the pump station desilting chamber. For high water levels in the river, water enters the desilting chamber via the periscope inlet, which lies in a vertical concrete shaft on the northwest corner of the pump station.

A desanding jet is located in the desilting chamber. Water entering the pump station flows over a baffle wall and spills into the pump sump on the same flow level as the desilting chamber, although the roof is somewhat higher.

Two centrifugal pumps and delivery columns are suspended in the well. The two pumps are double suction, vertical centrifugal pumps with an intended duty of 230 L/s each at a 21-m head, or 216 L/s at 22 m. Each is driven by a vertically mounted, 75-kW motor.

The pumps deliver water via a 600-mm, nominal bore, asbestos cement main to storage dam 1, which commands the North Block and has a total usable capacity of 19,600 m^3. The size of the dam was determined by the need to store water when no irrigation water is taken, based on a continuous pumping delivery of 210 L/s.

The main canal runs from storage dam 1 to the balancing dam. Immediately downstream of storage dam 1 is a cutthroat flume. Approximately 70 m from the dam is a long weir which regulates water level for the offtake to the distribution canal feeding part of the North Block. Two duckbill weirs farther down the canal regulate the water level for the distributor-controlled offtakes serving the southern section of North Block. Between the dam and the long weir, the canal capacity is 630 L/s, which falls to 450 L/s at the offtake. No further reductions are made at other offtakes.

The north distribution canal is designed to carry 180 L/s to simultaneously supply three fields. At seven offtakes feeding two sections, flow into the field canal is controlled by a Neyrpic distributor. These devices pass up to 60 L/s in 5-L/s increments. Water not channeled through these offtakes flows into a minor distribution canal. The rest of North Block is catered to by four minor distribution canals, each designed to convey 60 L/s, but their gradients are 1:600, while those of the minor distribution canals generally have gradients of 1:2,000.

The balancing dam is situated at the end of the main canal to enable pumping to take place at a constant rate. This is necessary since the flow in the main canal is likely to vary considerably. The balancing dam has a capacity of 6,900 m^3, which is sufficient for about 6 hours of pumping to the Central and South blocks.

The pumps in the central pump station are centrifugal and capable of pumping 165 L/s each against a 19.3-m head. They are driven by a 50-kW motor. Two hand-operated priming pumps are mounted on the pump station wall to prime the pumps before starting because of the relative levels of the pumps and the balancing dam.

The pump deliveries feed into a pipe that is connected to the 525-mm, nominal bore main leading from the balancing dam to storage dam 2. Storage dam 2 commands the Central Block and has a total usable capacity of 47,700 m^3. The size of the dam is determined by the need to store water at a time when no irrigation is taking place, based on a continuous pumping delivery of 285 L/s.

The central distribution canal runs northward from storage dam 2 to a duckbill weir, where three field canals are supplied. From the duckbill weir, the distribution canal runs eastward for 250 m to feed another four field canals. A cutthroat flume is located immediately downstream of the storage dam to measure flow. Flow into six of the field canals is controlled by Neyrpic distribution. Capacities are 840 L/s up to the duckbill weir, 480 L/s for the next 500 m, and 360 L/s for the final 250 m.

The Central Block field canals handle 120 L/s, and the gradient between drop structures is 1:1,000. Slots are provided on either side of the drop crests to accommodate checkboards, which are used to dam the water when siphoning is taking place.

Adjacent to storage dam 2 is the south pump station, which has one centrifugal pump capable of pumping 45 L/s against a head of 21.8 m. The pump is driven by a 18.5-kW motor. The pump delivers into a 200-mm, nominal bore pumping main which leads to storage dam 3. Storage dam 3 has a usable capacity of 5,400 m^3, which was determined by the need to store water pumped when no irrigation water is taken, based on a continuous flow of 45 L/s.

Pumped water is delivered to storage via asbestos cement pipes, while water is delivered from storage to field in canals by gravity. In the red soils the canals are concrete-lined, but in the black soils the canals are unlined. The canals incorporate drop structures to dissipate energy since the topography of the area frequently exceeds the design slope of the canals.

Upstream level is maintained relatively constant using side discharge spillways (or "long weirs" as they are locally known). The side discharge spillway is able to pass a wide range of flows with relatively small change in head over the crest. The spillway requires a change of inflow and outflow invert elevation, and is able to take advantage of the topography of the area. The combination of side discharge spillways and Neyrpic gates appears to be a successful one for flow control in this system.

Cutthroat flumes are used at each major discharge point to measure irrigation water. The flumes are manually read in liters/second using direct reading scales. It is not known whether or not the flumes have been independently calibrated.

An inspection of the irrigation system structures indicated that the system is installed as designed with the exception of a few minor differences in the extent of canals in the North and Central blocks. Since the system is little more than two years old, and because of the quality of construction, the structures are in very good condition. Some erosion of the unlined channels downstream of the drop structures due to turbulence was noted. In some places rip-rap has been placed to control erosion. Naturally occurring, decomposed basalt is readily available in the area, and additional rip-rap could be applied where needed.

One difference between the designed and existing structures was the removal of a 1-m^2 gate from the inlet/outlet chamber at storage dam 1. The gate was used to control flow into or out of storage dam 1. The gate was removed when water pressure in the dam pulled the guide bolt anchors out of the concrete of the inlet/outlet chamber. Consultation between the irrigation scheme manager and the consulting engineers indicated that the gate was usually fully open and its removal would not interfere with system operation.

One problem with the existing arrangement was that it was not possible to directly measure output from the river pump station by using a cutthroat flume and isolating storage dam 1. However, an indirect measure of pump performance was obtained (see page 29).

The irrigation system appears to be operating satisfactorily. The scheme manager is assisted by two pump attendants who operate the system, check the water stored in the dams, and inspect the condition of the system. The pump attendants perform a vital function for successful operation.

5. Land Preparation

Drainage. Surface drainage is provided throughout the system to convey runoff from irrigation. From inspection of the scheme, it was noted that little runoff from excessive irrigation occurs. The drainage system also conveys excess rainfall off the fields. The surface drainage system appears to be installed properly and to be functioning well. No subsurface drainage has been installed.

Land Levelling. When the system was installed, primary land levelling was done following land clearing operations. Disking was followed by normal cultivation prior to the first crop. Subsequent land levelling has not taken place, and although the land preparation appears adequate in most areas, there are low spots. In some cases, the undulations in surface topography are aggravated by shallow depths to bedrock which cause waterlogging, particularly in the South Block.

C. SOCIAL/INSTITUTIONAL SYSTEM

1. History

One of the primary objectives of the Tsovane scheme is to increase the area cultivated by the settlers. To meet this objective, ARDA began selecting settlers in 1984. An estimated 200 farmers formally applied for the 34 settler plots. Farmers were interviewed and their background was rigorously examined. Preference was given to those who had Master Farmer's certificates, experience in irrigated agriculture, and any cattle or cash in a bank indicating hard work and responsibility. ARDA also wanted settlers who were physically fit, under 50 years of age, and willing to leave their home and land on the communal lands. The settlers were expected to live and work full-time at Tsovane.

ARDA ultimately selected almost all the 34 settlers from nearby areas, including three female farmers. Some had irrigation experience and some did not. The settlers moved to Tsovane in late 1984 and immediately began an intensive six months of training in irrigation and improved agricultural techniques. The farmers were taken through all the cropping steps from planting to harvesting. Initially, the farmers did not like the training. They felt that they were being used by ARDA as laborers. Farmers now say, however, that it was excellent training.

2. Social Structure

Land. Each settler received a 2-ha plot of land and 150 m^2 for a garden plot. The farmers are on probation. If they produce crops in line with ARDA policy and cooperate, they will be allowed to stay on the land. ARDA has given each farmer a two-year lease on his plot, which can be extended. The land belongs to ARDA.

Technically, settlers were supposed to give up all land and cattle on their communal lands. Many settlers said, however, that some farmers turned over the cattle and land to a second wife or relative and, thus, still have some control over outside resources.

Almost universally, settlers expressed a strong desire to farm a larger plot of land, up to 4 ha. Settlers stated that as their knowledge of irrigated agriculture has increased, their desire for productive land has also increased. One settler stated that 2 ha is adequate if you are used to only dryland farming.

The settlers are unsure about the future of owning land at Tsovane. Some stated that they would be able to own land one day; others said that they did not know what the future would be. One settler claimed that it was unfair to ask farmers to give up all their dryland resources and come to Tsovane for a two-year probationary period. He said that if he is forced to leave Tsovane after two years, he will have nothing to support himself.

A female settler described the present land tenure system as "its my land and not my land. If I produce well, ARDA will allow me to stay and manage the land as I want. If I do not produce well, they will ask me to leave."

As of now, ARDA has no clear policy regarding increasing the plot sizes from 2 to 4 ha. Some ARDA officials felt that it would be better for Zimbabwe to give 2-ha plots to additional settlers, rather than increasing the plot size of the current 34 settlers.

Policy regarding whether or not to give eventual ownership of the land to the settlers is also not clear at the moment. One ARDA official did state, however, that if settlers were given ownership, or 4 ha of land, those settlers should be chosen very carefully using strict criteria to ensure that the land will remain productive.

The settlers' attachment to the Tsovane land is evident. One settler stated, "I'll stay here at Tsovane till death!"

Power. An individual's power is fairly well defined in rural Zimbabwe. Though education and political office are new indicators of power, the number of cattle owned is still an important determinant of a farmer's influence. Local chiefs are also still powerful. Indeed, this ARDA scheme was named after the local chief -- Tsovane.

ARDA officials work closely with the chief. The chief has cooperated with ARDA in stopping uncontrolled animal grazing on ARDA land, and the managers always seek the chief's help in obtaining labor. One settler stated that the settlers are at Tsovane because it is the chief's "will" that they come here to farm.

On the scheme itself, however, there are none of the old indicators of power. For instance, no settler is permitted to own cattle, and there are no chiefs. The settlers have had to define power in an entirely new way.

At Tsovane, settlers told us that everyone started out equal. No one was more powerful than anyone else. Since all were newcomers, settlers first had to get to know one another. Living so close to each other, settlers became acquainted very quickly and started to develop new indicators of power: leadership abilities, good crop management, and increased income. One farmer even stated that education was important, because one day one of the settlers might have to go to Harare to represent the settlement scheme. If so, that representative should know how to deal with government officials in Harare.

ARDA officials stated that witnessing settlers' meetings indicates that power is equitably distributed on the settlement scheme. During these meetings, settlers speak freely, often disagree with one another, and are not intimidated by other settlers.

3. Local Organizations

When the settlers first arrived at Tsovane, they worked with ARDA to form a farmers' committee. After the first year, the settlers divided their organization into two committees: a working committee and a village committee. The working committee helps solve disputes dealing with water or agriculture and serves as a link between ARDA and the settlers. If, for instance, someone misplaced the boundary markers between the 2-ha plots, the working committee would work with ARDA to re-establish the proper boundaries. The village committee is designed to help solve domestic problems within the settlement scheme.

Both committees are supposed to serve an important communication function. If a farmer has a problem, he is supposed to report it to a committee member, who talks with the ARDA settlement officer. If the problem is serious enough, the settlement officer talks with the estate manager. Similarly, rather than talk to each settler individually, the settlement officer talks to committee members about irrigation scheduling or other agricultural matters. The committee then informs the rest of the settlers.

Each committee has a chairman, vice-chairman, secretary, and treasurer, who are elected once a year. There is also a block chairman for each of the two, 34-ha settlement blocks. We were told that there are written by-laws for the committees. Another settler told us that during committee meetings settlers discuss ways to improve meetings and that the improvements are often adopted.

The chairmen of the committees do not have much decisionmaking power. Their main function is to preside at meetings and work closely with ARDA officials. The chairman do receive, however, a fair amount of respect from the other settlers. One settler stated that, ultimately, the chairmen should be elected on their record of high crop production.

The committees themselves also have little real power. The committee chairmen told us that if any of the settlers seriously violated ARDA rules, the committee would first warn the violator to stop. If he or she persisted, the committee would tell the settlement officer. It is ARDA, not the committees, that has punitive abilities and the power to force a settler to leave Tsovane.

ARDA also appears to have considerable power to influence settlers' organizational behavior. During the cotton season, for instance, ARDA insists that all settlers check their plots for pests on Tuesday mornings. On Tuesday afternoon, all 34 settlers are required to come to the estate office and complete a weekly chart documenting the level and frequency of pest infestation. During our study at Tsovane, all settlers attended this meeting. Two settlers who were late were criticized in a good natured way by the other settlers. A general discussion was then held regarding spraying for pests on Wednesday. ARDA officials had a pest infestation file for every farmer, and each farmer knew his file quite well. The meeting appeared to be disciplined and informative.

4. Social Services and Housing

There is a small health unit at the settlement camp staffed by one nurse. The nurse stated that malaria and diarrhea are the most prevalent health problems she encounters. She claimed that malarial mosquitoes come from water left standing after rains and that diarrhea is a result of settlers and estate employees drinking canal water. She said that she is not able to offer any primary health care extension services and that there are no facilities for pregnant or nursing mothers.

Farmers' wives in the settlement area said that due to increased income, their lives are now better than when they were on communal lands. They have access to clean water and are pleased that they can grow fruit trees in their yards. As the males at Tsovane must work on the 2-ha plots, the farmers' wives claimed that their workload is minimal.

They did complain, however, that there was no easy access to stores or a hospital. One woman stated that she had to walk 1 to 2 km to a store even if she only wanted to buy a box of matches. Women also complained that the 2-ha plots were too small and more income could be generated with a 4-ha plot.

By far the biggest complaint of all Tsovane settlers, however, was inadequate housing provided by ARDA. Everyone complained that a small, two-room house with a shower, latrine and potable water was not adequate. Settlers stated that with their wives and children, two rooms were not enough, particularly when their children reached puberty and males and females had to share a room. Additionally, others complained that after harvesting cotton, the crop is dried in the yard during the day, but must be placed indoors at night. This effectively reduces their quarters to one-room houses. Other settlers said that they were not allowed to add additional rooms to their houses.

Some ARDA officials sympathized with these complaints, but pointed out that the settlers were, in essence, receiving free housing. Also, the alternative to the two-room house was a mud dwelling with no latrine or drinking water. These officials also stated that ARDA is in the business of managing viable agricultural estates, and housing is not their area of expertise. In any event, they claimed that policies for ARDA housing are set in Harare, not at Tsovane.

5. Settlers' Lives and Felt Needs

Every settler contacted said that their life at Tsovane was better than it was before Tsovane. Increased income and improved standards of living were the primary reasons given for a better life. One female settler said that she used to "thirst" for money for food, school, and household items. Now she says she no longer has "sleepless" nights worrying about planning for the future. She knows that if she works hard, she will make some money.

Another settler stated that he now had aspirations for his life. Before he moved to Tsovane he could aspire to nothing. Another settler was pleased that he had learned how to properly farm cotton and wheat. Others praised the spirit of community development and "oneness" started at Tsovane.

Some ARDA officials claimed that the settlers now strongly identify with the Tsovane scheme. They stated that when settlers travel to the nearby town of Chiredzi, the settlers almost brag to the townspeople that they come from the Tsovane scheme.

The strict regimentation practiced at Tsovane did not appear to bother the settlers. One said that such a tightly regulated life was good because it provided an income and security. Regimentation was bad, however, if the settler learned nothing from the experience and just passively obeyed orders.

A large concern of the farmers was that it takes so long to receive their earnings from the Agricultural Finance Corporation (AFC). Settlers felt that they had followed AFC and ARDA rules closely, but that AFC had not. Some farmers waited six months for their earnings.

In general, farmers desire titles to the land, larger plot sizes, and better housing. Though ARDA is sympathetic to many of their felt needs, they cannot currently promise these things to the settlers.

6. Tsovane Scheme Employees

Tsovane scheme employees were generally pleased with their working conditions, though they complained of low pay. They live in the same housing as settlers and also complained about the adequacy of the housing. One worker said that the housing was adequate only because his salary was so low he could not afford to buy household items to put in the house.

Two of four workers interviewed said that they would prefer to be settlers rather than ARDA employees. They thought settlers earned more money, and the workers' dryland plots on communal lands were producing very little.

The two workers who did not want to become settlers said that they could not see any advantage to becoming settlers. One of these workers was a farm machinery operator who did not want to give up an interesting job.

7. Tsovane Scheme Management

Managers at Tsovane felt that the scheme was successful. One manager said that an open style of management with public praise for good employees was helpful. This led to motivated, cooperative employees and settlers who were committed to making the scheme work.

A high-level ARDA manager attributed Tsovane's success to hand-picked estate managers who are thoroughly trained. He also felt that constant attention to estate maintenance helped the scheme.

A middle manager saw three lessons from the apparent success of the settlement scheme. First, carefully select serious and responsible people to be settlers. Second, train the settlers hard and well. Third, do not allow settlers to hire labor to do all the farming operations; make sure the settler performs his (or her) operations and develops a sense of commitment and ownership.

One of the scheme managers stated that ARDA in Harare does not interfere with his operations too much. As long as the scheme makes a profit, he felt that ARDA would let him manage the scheme as he saw fit. He also thought that ARDA was wise to keep managers at one scheme for a number of years (approximately 3-5 years). He stated that in the past, ARDA transferred its managers before they had a chance to make an impact on a scheme.

Tsovane management did have two specific concerns. First, they were concerned with the future of the 54 Tsovane estate employees as the settler lands expanded. Managers did not know what would happen to these workers, though they felt that some might want to become settlers. Since the employees would not require six months' training, the managers thought this would be a viable option.

Second, they wondered how the settlers will be able to maintain and operate the scheme's heavy machinery. Managers had no ready solution to this problem, save for maintaining a strong ARDA presence at the scheme, even after the settlers have most of the land.

8. Future of Settlement Scheme

Most of the settlers seem to have a vague notion that when more settlers come to Tsovane, ARDA may take a smaller role. If that happens, many settlers felt that their committees would need to be strengthened to take over some of ARDA's roles. For instance, settlers realized that they would have to receive intensive training to take responsibility for the heavy machinery. One settler insisted that if ARDA gradually lessens its role at Tsovane, some competent authority should remain to maintain the two pumps on the Middle Save River. Another settler felt that without ARDA, the settlers would start to grow many different crops each season. Any future committee, he said, should continue to demand that all farmers grow just one main crop per season, making irrigation much easier. One settler believed that after five years of further farming and training, the settlers would be able to do things for themselves. He said, "After five years, we'll be perfect farmers."

Among the issues still unresolved at Tsovane is what to do with settlers when they become older. Will they be asked to leave the scheme to make room for younger farmers? Will they be able to remain on the land? ARDA has not reached a decision on this issue.

D. CHARACTERISTICS AND PERFORMANCE OF SYSTEM MANAGEMENT

1. Water Distribution in the Main System

Irrigation water taken from the Save River flows south for 32 m to the river pump station, where it is routed to storage dam 1. Storage dam 1 commands the North Block. The North Block is divided into six sections, each comprising several fields. The system allows one field in each section to be irrigated at the same time. The six sections are designated NA, NB, NC, ND, NE, and NF (Figure 1). For instance, fields NA2, NB3, NC5, ND4, NE1 and NF6 may all be irrigated at once. A summary of the water distribution system is in Table 1.

Table 1. Summary of water distribution system in the North Block of Tsovane.

Section	Supply Canal	Initial Supply Point
NA	MDC*2	Distributor beside dam 1 outlet
NB, NC	North distribution	Distributor offtake from north distribution canal for each field canal
ND	MDC 1	MDC fed by north distribution canal
NE	MDC 3	Distributor at duckbill weir 1
NF	MDC 4	Distributor at duckbill weir 2.

*Minor distributary canal.

The Central Block receives irrigation water from storage dam 2. The Central Block is designed so that fields C1 to C6 and one of fields C7 (a, b or c) may be irrigated at once. Flow to fields C7 (a, b and c) is controlled by placing boards in the drop structures at the start of canals C7a and C7b and on the adjacent distribution canal. Two boards are placed, allowing all the flow (120 L/s) to go to the remaining field.

Storage dam 3 commands 32 ha in the South Block. The field canals are gravity fed with flow being distributed one way or the other by a mini long weir and a slide gate below the dam.

Measurements were taken to estimate output from the river pumps. In the absence of water flow measuring devices in the pump house, measurements were taken in the following ways:

1. At the main pipe outlet chamber.

2. At the cutthroat flume immediately downstream of the chamber.

3. In the main canal using a current meter.

The average for the pump output was 240 L/s at 77 percent efficiency, against the rate capacity of 230 L/s at 84 percent efficiency.

Generally, conveyance losses in the lined canals of the North Block are almost negligible. However, some minimal operational losses occur at the tail ends of the canals into the surrounding woods.

Tests were carried out in the Central Block unlined canals using the inflow-outflow method over 700 m. The tests involved using a current meter and Neyrpic gates. Measurements were taken using the drop structures as weirs. Seepage loss averaged 0.25 percent per 100 m.

2. Water Distribution in the Farm System

Furrow slopes on the North and Central Blocks are uneven; ie., more or less flat at the head and steepening towards the tail. The general grades are 1.12 percent and 0.75 percent for the red and black soils, respectively. Clods and dead weeds tend to distort the furrow shape and dimensions. End checks are installed at the tail of the furrow to stop run-off, but they result in ponding.

The field irrigation system is operated by two irrigators. The irrigator at the head operates the siphons, adjusts the flow at the Neyrpic gates when necessary, and cleans the furrow. The tail operator monitors the advance phase and signals to the head operator to remove the siphons at the end of an irrigation.

Siphon tube sizes used on the scheme are 25 mm, 32 mm and 50 mm in diameter. The flow into the tertiary canal is regulated by Neyrpic gates.

Two methods of irrigation are employed on the red soils due to the alignment of furrows and the tertiary canals. One method is direct siphoning from a canal into the field furrows. The other method is to divert flow from a canal into a leading furrow using siphons, and then use spiles to divert the flow from the lead furrow into the field furrow.

The 25-mm siphon is used on the red soil and the flow is shared by two furrows. At a siphon-head of 0.12 m, the discharge from a 25-mm siphon was estimated at 0.35 L/s. On the black soils, both the 32-mm and 50-mm siphons are used. The flow from the 50-mm siphon is shared by 2 furrows, whereas the 32-mm siphon serves one furrow. The discharges from the 32-mm and 50-mm siphons at a siphon head of 0.49 m were estimated to be 1.18 L/s and 3.33 L/s, respectively.

Intermittent irrigation is practiced due to erosive flow, siphon size, and furrow slopes, and the siphon head is regulated to reduce the erosion hazard and topsoil wash.

The operational time per day is 9 hours, which gives 8.5 hours of full irrigation. The normal practice is 4 to 5 hours on the red soils and 5 to 6 hours on the black soils.

General Conclusions. With cotton growth at 4 to 6 weeks, a 5.5-h furrow irrigation period, a run length of 300 m, and a 32-mm siphon tube, the irrigation depth was estimated to be 78 mm. The actual required depth is 40-45 mm, and the estimated field application efficiency is 47-52 percent. Under similar conditions, it takes a 50-mm siphon tube only 0.7 hours to complete the irrigation. This results in an irrigation depth of 29 mm, which is not adequate.

On the red soils with a run length of 120 m, a 25-mm siphon-tube, and the cotton growth stage between 9 and 12 weeks, intermittent irrigation tends to result in over-irrigation at the head, giving a somewhat lower field application efficiency. It would appear that deficit irrigation is not practiced on the scheme.

General Recommendations. On the black soils, a 50-mm siphon can be used during the early growth stages of the crop. Later, the farmer can change to a 32-mm siphon in order to apply the correct quantity of water. Another alternative is to split the flow from a 50-mm siphon into two furrows. On the red soils, a 32-mm siphon would be more appropriate, with the flow shared between two furrows.

3. Water Adequacy, Reliability and Equity

Crop Water Requirements. Using ARDA figures (i.e., crop coefficients, growing season data), the water requirement is 763 mm for cotton, and 512 mm for wheat.

ARDA considers effective rainfall to be 300 mm in the summer and zero mm in the winter. Given the erratic distribution of rainfall in the low veld, a more conservative estimate is warranted. Based on an available water capacity of 100 mm/m for the red soils, the suggested irrigation schedule for the red soils is 7 days with 60 to 70 mm net application. For the Vertisols, with an available water capacity of 180 mm/m, the rotation should be 14 days with 108 to 126 mm net water applied.

Water Adequacy. During normal river flow, adequacy of water supplies does not seem to be a problem. In dry periods, adequacy depends primarily on the capacity of the upstream dams (Ruti and Rusape) to meet the supply deficits of all the downstream water users along the Save River. This has not been a problem so far.

In periods of extreme drought, however, low water levels in the dam will probably result in water rationing. When this occurs, priority in water supply is given to the settler farms on the South Block of the scheme, and the estate manager decreases the irrigated hectarage in the estate section of the scheme.

Another aspect of adequacy worth mentioning is that in periods of high evapotranspiration, it would be difficult to irrigate on schedule (once a week) on the red sandy soils of the North Block. There is a need to investigate the moisture release characteristics of this soil. Such a study could be undertaken by the Department of Soil Science and Agricultural Engineering at the University of Zimbabwe.

Water Reliability. Reliability of water supply depends on the following factors: river discharge, pumping stations, and operation of canal systems.

River discharges are generally reliable, and the estimate of 756 m^3/h is normally satisfied at the pumping station. In the two years of operation, shortages have not occurred. It can be anticipated, however, that during extreme drought (as in 1983-84) river discharges may be unreliable and the special provisions for extracting water from the riverbed will have to be put into effect.

The continued good operation of the pumps is the most critical index of reliability of supplies within the system. Good maintenance and adequate supplies of replacement parts are essential for having reliable supplies.

Another temporary operational measure used to maintain reliability of water deliveries is to maintain high levels in the night storages. These storages are estimated to provide 6-7 days of supplies when full, which provides a buffer when pumps break down.

Timely opening and closing of gates is also essential to ensure the reliability of water supplies. Two gate tenders open and close the gates at Tsovane. They did their work very capably and conscientiously. Even so, installing discharge measuring structures at the pumps and staff gauges in the storages would help them improve their performance.

Equity. Observations show that equity is not a problem so far as water deliveries are concerned because the system operation is highly controlled. Farmers perceptions confirmed this and also that conflict regarding water delivery is virtually non-existent.

4. System Management

Farmer Involvement in Irrigation Activities. On each of the 34-ha blocks farmed by settlers, five settlers irrigate at the same time, each using eight siphon tubes. When these five settlers are finished, the irrigation water is moved down the canal to the next five farmers. All settlers said that they receive water on time, and each settler receives the same amount of water. Water is delivered to them about every 12 to 14 days. They are very pleased with the irrigation arrangements and reported no water thefts.

Each settler is responsible for maintaining the section of the canal adjacent to his 2 ha. Farmers appear to scrupulously maintain their sections. The settlers have been told not to pull grass and weeds from the canal banks, but rather to "shave" the growth close to the banks.

Farmers expressed no interest in becoming more involved in irrigation operations and decision-making or to control main system water deliveries to their fields. They said they are currently receiving all the water they need when they need it and see no reason to change the system.

Settlers stated that the settlement officer worked closely with them, informing them when water would be delivered. Settlers expressed a great deal of trust in this officer, whom they said always delivered water to them reliably and helped them in their irrigation operations. One settler said that the "cotton is talking," and that is when ARDA supplies them with water.

When a settler receives irrigation water, he is required to be at his field. No "trading" of turns is allowed. If there is an important social event (i.e., wedding, funeral) that he feels he must attend, he must arrange for a family member to remain at his plot to irrigate. Discipline is very strict on the scheme.

A few farmers did complain that their irrigation water sometimes stops at 3:00 p.m. when the ARDA field employers stop work for the day. These farmers wanted to know if there was a way to continue water deliveries past 3:00 p.m. (If a settler does not finish irrigating when deliveries cease, he can begin to irrigate again at 6:00 the following morning.)

One of the managers on the estate said that he favors farmer involvement in irrigation activities. He said, however, that farmer involvement must be carefully implemented. He warned against giving farmers total control of the system, just for the sake of participation. He stressed that involvement should take place productively.

Conflict. There seems to be little conflict over water at Tsovane. At the settlement scheme, no one reported any water conflicts. One settler attributed this to the settlers still fearing ARDA discipline if serious disputes did arise.

Some settlers said that when they arrived at Tsovane in late 1984, there were disputes over some of the boundaries of settlers' fields, but that these were quickly resolved. Settlers mentioned that if they do have disputes or problems, they talk with the Tsovane settlement officer, who resolves the issue. The settlement officer spends much of his time with the settlers in their fields.

If there is any potential for conflict, it might revolve around the issue of housing. Settlers are unhappy with their housing, but local ARDA staff do not seem to have the power or authority to make changes.

5. System Maintenance

Pump maintenance. The estate has an agreement with a private firm in Chiredzi to service their pumps annually on a per cost basis in terms of labor, spares and mileage. Also, the company operates on call for any pump problems at any time.

Canal maintenance. Main system maintenance is the responsibility of the ARDA estate. There is contract labor for nine months to clean the canals. The lined canal section is cleaned by an estate employee before or after an irrigation season, which usually entails removing sand. To date, no concrete-lined canals or other structures are broken. In unlined canals, the only maintenance is cutting grass, and this is done by contract labor. In the settler section, canal maintenance is the responsibility of the settlers. We recommend that, around unlined canals, the grass be kept short, but not removed, in order to check erosion.

In general, the system is in good order in regard to maintenance. On the estate it appears that most of the unlined canals have low priority.

E. CHARACTERISTICS AND PERFORMANCE OF THE AGRICULTURAL SYSTEM

1. Agricultural System

A cotton-wheat rotation is practiced in summer and winter, respectively. Sugar beans can also be grown in the winter. The main reason for practicing this rotation is to facilitate loan payments to The Agricultural Finance Corporation. Payments are deducted at the Grain Marketing Board (GMB) or Cotton Marketing Board (CMB) before checks are made to the farmers.

The summer crop during the study was cotton, variety Albar K602, supplied by the Cotton Marketing Board. The cotton was planted in October 1986, and on average, looked healthy, with minimal signs of pest damage on all blocks belonging to settlement farmers. Fairly heavy spider mite damage was observed, however, on some of the estate blocks. Farmers and scouts check for spider mites, jassids, white flies, bollworms, and others, to determine when to apply pesticides. Acaricides are applied using the recommended chemical for the area and year based on the acaricide rotation cycle in the country.

Cultural Operations. Early operations -- namely disking, furrowing, initial fertilizer application, pre-emergence herbicide application, and planting -- are all done by ARDA. The farmer is responsible for thinning, weed control, and top-dressing with nitrogen. In addition, the farmer looks for insect pests and diseases and harvests the crop. Rough measurements showed crop spacing for cotton of about 100 cm between rows and 25-30 cm within the row, giving a plant population of about 37,500 plants per hectare.

Cotton had been fertilized for the past two seasons at the rate of 200-300 kg/ha of compound P and 100-200 kg/ha of ammonium nitrate. The ammonium nitrate is applied as top-dressing at the 6-week and 10-week stages of growth. Fertilization rates are based on soil analysis results taken to a depth of 30 cm.

Irrigation Scheduling. On the black Vertisols, available water capacity is estimated to be 18 percent; while on the red soils, available water capacity is estimated to be about 10 percent. An irrigation cycle of 14 days on the Vertisols and about 7 days on the red soils seems to be appropriate. Scheduling is based on a soil moisture depletion of 70 percent during the early vegetative phase, 60 percent at first flower production throughout peak flowering period, and 70 percent thereafter.

On the average, the irrigation schedule appears to supply adequate water at the appropriate time. However, a measurement device is needed to determine if the volume is truly delivered to the field.

Cotton Yield. Table 2 shows mean yields and ranges for blocks C1, C2 and S1 for settlement farmers and estate blocks (R1, R35, C3-C9 and S1 - S2) for 1985/86 season.

Differences between blocks C1, C2 and S1 taken two at a time were significant. The order of magnitude of block mean yields was C2 > C1 > S1. On average, mean block yields on settlement plots were greater than those on estate blocks, probably because of differences in managing a small plot compared to managing a larger area of the estate. Both settlement and estate mean yields were fairly comparable to experimental mean yields for this crop in the low veld (DRSS Annual Reports).

Table 2. Mean cotton yields for Tsovane settlement and estate blocks.

Blocks	Mean Yields (kg/ha)	Range (kg/ha)
Settlement farmers		
C1	3731.6	3075 - 4193
C2	3925.1	3398 - 4546
S1	3366.0	2904 - 3607
Estate		
R1 - R35	2905.3	1513.3 - 3898.8
C3 - C9	3183.7	2682.0 - 3740.8
S1 - S2	2632.5	2475.4 - 2789.5

Differences among blocks for estate yields were also detected, and the order of magnitude was C blocks > R blocks > S blocks. The consistently lower mean yields of the S blocks compared to the R or C blocks was probably due to restricted root development caused by the relatively shallow soils in the S blocks.

Wheat Yield. Wheat yields for the seasons 1984/85 and 1985/86 were compared between blocks C1, C2 and S1 for settlement farmers only (Table 3).

Table 3. Mean wheat yields for settlement farmer blocks for two seasons in Tsovane.

Blocks	Season	Mean Yields (t/ha)	Range (t/ha)
C1	1984/85	2.70	1.5 - 3.3
	1985/86	4.64	4.1 - 5.8
C2	1984/85	2.74	1.6 - 3.6
	1985/86	4.97	4.5 - 5.8
S1	1984/85	1.86	1.5 - 2.1
	1985/86	4.64	4.2 - 5.2

The difference between the mean of S1 and the mean of C1 and C2 was significant for the 1984/85 season. No significant differences were detected among blocks for mean yields in the 1985/86 season. On all blocks, differences among seasons were significant. The lower yields during the 1984/85 season were mainly due to delayed planting and use of uncertified seed.

The 1985/86 mean yields for all blocks were marginally lower than low veld experimental yields (5.7 t/ha for variety Torim 73), but marginally higher than commercial farm yields (3.9 t/ha; AGRITEX, 1982) or ARDA estate yields (3.9 t/ha; Source: Central Statistics Office, Harare).

Fertilizer inputs for wheat were 300 kg/ha of compound D (8:14:7) and 50 kg/ha of ammonium nitrate applied as top-dressing. The rates were similar for the two seasons, and in both cases, the recommendations were based on soil analyses by the chemistry branch of the Department of Research and Specialist Services (DRSS). As with cotton, initial fertilizer applications, planting, furrowing, and other operations were done by ARDA, and the farmer was responsible for the crop from emergence to maturity. Wheat was planted in early to mid-May for the 1985/86 crop.

General Comments on Crop Yields and Farmer Practices. Within blocks, fairly wide variability was observed among farmers' mean yields as shown by the ranges in Tables 2 and 3. Some farmers' performances were inconsistent between the two wheat seasons; i.e., contrasts among means differed from farmer to farmer. Some farmers consistently produced higher yields, while others consistently produced lower yields.

The reasons for this variability among farmers could be attributed to differences in managing their fields from emergence of the crop to harvesting. For cotton, this would involve differences in timing the thinning, weed control, effectiveness of scouting for and controlling insects and diseases, and top-dressing. While some farmers were observed to be very thorough in scouting for pests, others were not as detailed. Scouting, however, is unlikely to cause a major difference in yield performance among farmers because what the farmers miss would normally be picked up by the trained scout.

The topography of some of the plots was uneven. In one plot, furrows were not continuous from one end of the field to the other. This resulted in waterlogging in some areas and probably under-irrigation in other areas in the same plot. Waterlogging or under-irrigation would affect nutrient availability to the plants.

Farmers were keen to continue growing cash crops rather than food crops for subsistence. They generally felt that 4 ha would be a better size of plot per settlement farmer than the current 2 ha.

A worker on the estate just outside the scheme said he grew maize on his land because his children preferred the taste of maize than that of sorghum or millet, which are more drought-resistant than maize.

2. Production Inputs

The production inputs used by the farmers include improved, certified seed, which is readily available from the marketing boards. For cotton seed, the farmers use a variety recommended for the low veld. For wheat, the variety Limpopo is recommended for the low veld. The farmers use the recommended seed rate.

Fertilizer use is as recommended from the Soils and Chemistry Institute of DRSS. The rate recommended is 300 kg/ha of compound D (8:14:7) and ammonium nitrate top-dressings of about 100 kg/ha. Farmers and the core estate use pesticides as dictated by the pest scouting, especially for cotton.

Farmers receive most of their extension information from the settlement officer, who advises the farmers and also checks whether they are giving enough attention to their fields or not. Farmers received training on system operation during the first six months, when they were employed by the estate to give them experience.

Currently, farmers are trained to check for pests in the fields by checking for pests themselves, followed by another check by the check scout. The results are compared. This training will give farmers knowledge of pests that are common on their farms. In addition to scouting, farmers are present when the settlement officer dilutes the chemicals so that the farmers may eventually learn to dilute the chemicals themselves. Farmers also receive refresher courses on scouting for pests, which they pay for and which is included in the crop budgets.

Credit is readily available through the Agricultural Finance Corporation, which extends seasonal loans to the farmer and then deducts the premium and interest from the farmer's gross income. The farmers do not receive the buying orders. Rather, ARDA receives the orders and purchases the inputs for the farmers, which are then used on the land.

3. Prices and Marketing

The price and marketing mechanisms are out of control of the farmers. Prices are set by the government with some lobbying from farmer organizations. The price used is the price of the crop before planting, and is usually announced before plans are made for the season at hand. The farmers take the price as given and produce to attain the highest yield and the best grades, since there is a price differential between crop grades.

The crops grown at Tsovane are controlled. Therefore, they have to be marketed through the parastatal marketing boards responsible for the particular crop. Wheat is sold to the Grain Marketing Board and cotton to the Cotton Marketing Board. It is through these marketing channels that AFC recovers its loans from the farmers using a stop order system. At Tsovane, farmers and the core estate are satisfied with the functions of the marketing boards.

F. FINANCIAL AND ECONOMIC PERFORMANCE

Tsovane is a very productive and highly structured scheme, and is unquestionably effective in terms of increasing rural income. However, three issues seemed less clear. First, the highly structured system provides effective marketing arrangements with marketing boards and a mechanism for obtaining adequate quantities of agricultural inputs (such as fertilizer and seed) and delivering them in a timely fashion. This highly structured system has some drawbacks. For example, a good deal of dissatisfaction was voiced about the mandatory housing provided by ARDA. However, there is little doubt that the effectiveness of the settlement officer in serving as an expediter is one of the principal reasons for the high productivity of the scheme.

Second, while the pumping system has worked well, the success of the scheme is tied to a single pumping plant. In the advent of a major breakdown, it is likely that the scheme would be without water for some time. If many such schemes were developed, it would be highly desirable to develop a contingency plan which would allow for rapidly restoring pumping service after a major breakdown. The need for such assurance not only involves the crop affected by a breakdown, but also the attitude farmers have about the reliability of the scheme. Farmers must be confident about the availability of all inputs, including water, if they are to develop the ways of thinking about farming their land that are necessary for the existence of intensive agriculture.

Third, the objectives of obtaining adequate farm family incomes, obtaining payment of O&M and capital costs, and having small plot sizes with many settlers, conflict with one another. While there is no one correct way to resolve this conflict, policy makers must understand the relationships among these objectives if they are to develop realistic expectations for rehabilitating an existing scheme or developing a new scheme.

1. Scheme Costs

Anticipated Capital Development Costs. The anticipated capital development costs for ARDA for the 338 ha in Tsovane totalled $3,601,045 or $10,654/ha (ARDA, 1982, pp. 13-15). We were not able to obtain the actual development costs, but we were told by a local ARDA official that actual costs were very close to anticipated costs (Table 4).

ARDA Maintenance and Operation Costs. The anticipated ARDA maintenance and operation charges (ARDA, 1982, p. 23) are presented below in Table 5. The average annual anticipated cost per hectare would be $127.25. We were not able to obtain actual O&M costs. These O&M costs do not include the cost of electricity used for pumping.

Settler Development Costs. Settlers received plots which were fully developed, although many farmers have done additional land leveling in conjunction with their regular field work. Settlers also moved into a completed housing project, but voiced dissatisfaction with housing due to the small size of the houses and the absence of storage space. Farmers were provided with 150 m^2 of garden space, which settlers stated was not large enough to satisfy household needs.

Table 4. Anticipated capital development costs for Tsovane (ARDA, 1982).

Item	Anticipated Costs ($)*
Civil works	1,489,500
Mechanical and electrical	215,500
Agricultural works	251,000
Domestic water and sanitation	112,000
Subtotal	2,068,000
20% preliminary and general	413,600
Housing and building	349,000
10% preliminary and general	34,900
10% contingencies	286,550
Agricultural and building machinery	208,995
Engineering costs of professional fees	240,000
Total Scheme Costs	3,601,045

*In Zimbabwe dollars.

Table 5. Anticipated maintenance and operation costs* at Tsovane (ARDA, 1982).

Item	Cost ($)	Percent Charged	Cost Per Year ($)
Intake work and pump stations	122,100	2.0	2,442
Plant and equipment	181,500	9.0	16,335
Pipelines	321,200	0.5	1,606
Storage	245,850	0.5	1,229
Main canals and structures	133,100	2.0	2,662
Field canals and structures	404,800	3.0	12,144
Field roads and drains	275,000	2.0	5,500
Irrigation attendent housing	16,500	2.0	330
Total cost per year			42,248
Average cost/ha/yr			125

*In Zimbabwe dollars.

Pumping Costs. No attempt was made to update the initial construction cost of the pumping and water distribution system.

The anticipated electrical cost for the scheme (ARDA, 1982, Appendix E) was \$1.36/1000 m^3 for the river pump, \$1.54/1000 m^3 for pump 1, and \$3.26/1000 m^3 for pump 2. Therefore, the anticipated cost of lifting the 7,436,000 m^3 from the river was \$1.36/1000 m^3. The anticipated cost per 1,000 m^3 of the 496,000 m^3 delivered into the storage reservoir for South Block was $6.16/1,000 m^3. The average weighted anticipated cost for the electricity used to lift the water on Tsovane was $1.66/1,000 m^3. Since the gross diversion is 11,000 m^3/ha each season on Tsovane, the cost to lift water each season per hectare is $18.26. The schedule of electricity rates has not changed since the construction was planned, although rates may soon be increased. Local irrigation officials said the actual pump performance was at least as good as anticipated in the planning process.

The major cost of lifting water was embedded in the cost for building and maintaining the pumping stations and the network of pipelines and canals which tie the systems together. Once the scheme had been developed, from a strictly economic standpoint, little added investment could be justified if the objective of that added investment was to conserve water in order to conserve energy. The reason for this conclusion follows.

The current irrigation efficiency is 47 percent -- a gross diversion of 11,000 m^3/ha each season results in a net application of 5,170 m^3/ha each season. If the overall efficiency could be raised to 80 percent (which is an efficiency level that probably could not be obtained), a net application of 5,170 m^3/ha each season would require a gross diversion of 6,463 m^3/ha each season.

As the result of this change in irrigation efficiency, the cost per hectare each season of electricity for pumping would decrease from $18.26 to $10.73 -- a savings of $7.53/ha each season or $15.06/ha each year. This savings of $15.06/ha each year could be used to finance a one-time improvement that cost $106/ha if the improvement had a 20-year life, no salvage value, and an interest rate of 13 percent was used. It would not be possible to increase irrigation efficiency from 47 percent to 80 percent with an investment of only $106/ha. In comparison, the annual irrigation charges to settlers reflected in the 1985/86 crop budgets were $120/ha each year (Tables 6-9). The anticipated O&M costs in 1982 were $124.99/ha each year.

The general nature of this conclusion would hold even if the cost of electricity doubled. This is not to say that energy costs and energy use are not significant problems from a national viewpoint. However, from the standpoint of the farmer on an irrigation scheme, other costs are much more significant. For reasons mentioned earlier, of much greater significance to farmers are the reliability of the supply of electricity and the resulting reliability of the supply of irrigation water.

2. Crop Budgets

The crop budgets indicate the input-output relationships within the farm operation. Although actual crop budgets differ from season to season, the farmer should aim to predict his costs and benefits as accurately as possible. Since budgeting is a management planning tool, poor budgeting will usually lead to poor management. The crop budgets at Tsovane were differentiated into two categories: budgets for the settler farmers and budgets for the core estate.

Table 6. Gross margin budgets per hectare of estate cotton (Tsovane)*.

	1984/85 Budget	1984/85 Actual	1985/86 Budget	1985/86 Actual	1982 Planning Budget
Yield (kg/ha)	2750	2880	3500	3057	2000
Price/kg ($)	55	55	64	66	50
Income ($)	1512	1665	2240	2004	1300
			------$------		
Variable Costs					
Levy					18
Aircraft hire	57	28	8		60
Miscellaneous					11
Fertilizer	132	132	154	151	62
Herbicides/ weed control	33	6	46	9	included in pesticides
Insurance	2		4	3	3
Irrigation					
electricity	92	38	76	48	
water	60	8	60	17	19
Land preparation (tractor usage)	133	222	192	178	142
Labor					
regular	178	134	53	75	
casual	55	188	66	138	
contract	165	139	212	180	120**
Packing (materials)	15	11	9	29	5
Pesticides/ defoliants	131	88	199	136	97
Seed	5	5	4	9	4
Transport out	20	38	35	45	31
Total Variable Costs	1048	967	1118	1018	572
Gross Margins	464	698	1122	986	728

*In Zimbabwe dollars.
**Includes regular labor, casual labor, and contract labor. Source: Tsovane ARDA Estate and Project Document (1982).

Table 7. Gross margin budgets per hectare of estate wheat (Tsovane).*

	1985/86 Budget	1985/86 Actual	1982 Planning Budget
Yield (kg/ha)	4000	4000	3500
Price/kg ($)	28.5	28.5	19
Income ($)	1140	1140	665
		---$---	
Variable Costs			
Aircraft hire	8		
Fertilizer	180	260	144
Herbicides	8		
Insurance	3		3
Irrigation			
electricity	75	42	
water	60	18	24
Land preparation	75	27	134
Labor			
regular	31	31	
casual	18	55	
contract			
Mechanical harvesting	70	101	
Packing materials	6	15	
Seed	75	131	23
Transport	44	40	33
Levy			3
Miscellaneous			9
Total Variable Costs	677	781	488
Gross Margins	463	359	217

*In Zimbabwe dollars.

Table 8. Wheat crop budget for Tsovane settler farmers (1985/86).*

	Budget (1.0 ha)	Budget (2.0 ha)	Budget (68 ha)	1982 Planning Budget ($/ha)
Yield/ha	3500	3500	3500	3000
Price/t ($)	280	280	280	190
Income ($)	980	1,960	66,640	570
	----------	----------	$ ----------	----------
Variable Costs				
Land preparation	91.76	183.52	6,230.80	42
Fertilizer & transport	168	336	12,648	144
Labor wages	42	84	2,856	
Seed	75	150	5,100	23
Mechanical harvesting	95	190	6,460	60
Packing material & twine	80	160	5,440	
Water & electricity	60	120	4,080	24
Drawings & advances	30	60	2,080	
Crop insurance	6	12	408	
Miscellaneous				6
Levy				3
Seasonal credit				22
Transport				33
Total Variable Costs	655.76	1,311.52	44,936.68	357
Gross Margins	314.24	628.48	21,708.52	213

*In Zimbabwe dollars.

Table 9. Gross margin budget for Tsovane settler farmers per hectare and for 68 ha (cotton, 1986/87).*

	Budget (1.0 ha)	Budget (68 ha)	Budget (2.0 ha)	1982 Planning Budget (1.0 ha)
Yield (kg)	3200	3200	3200	2000
Price/kg	.66	.66	.66	.50
Income ($)	2,112	143,616	4,224	1,000
<u>Direct Costs</u>				
Land preparation (tractor usage)	138	9384	276	42
Herbicides (Trif) 3.5 L/ha	28	1904	56	
Fertilizer compound L (300 kg/ha)	102	6936	204	
AN (200 kg/ha)	72	4624	144	62
Seed (35 kg/ha)	8.40	517.20	16.80	4
Irrigation water	60	4080	120	19
Labor wages	103	7004	206	
Harvest (3200 kg/ha at $.07/kg)	224	15232	448	
Transport to markets	48	3264	96	25
Pesticides and fungicides	316.14	21503.64	632.28	78
ULV battery charges	6	408	12	
Miscellaneous				5
Levy				13
Seasonal credit				21
Packing materials				4
<u>Indirect Costs</u>				
Land rent	100	6800	200	
House rent	40	2720	80	
Crop insurance	3	204	6	
Total indirect	143	9724	286	
<u>Other Costs</u>				
Refresher courses and check scout	25	2040	50	
Total Variable Costs	1,286.13	87,456.84	2,572.26	273
Gross Margins	825.87	56159.16	1651.74	727

*In Zimbabwe dollars.

The budgets for the settler farmers are constructed so as to give farmers an indication of the working capital they will need. The budgets are then used to apply to the AFC for loans. The settlement officer, in association with the farmers, constructs the settler budgets.

The estate budgets are constructed by the estate manager in order to estimate the inputs required to grow particular crops on the estate. The estimates for required expenditures are presented to the ARDA head office for approval.

The budgets indicate that farmers are more efficient producers than the core estate. From the budgets it can be seen that the core estate has higher costs than the settlers if indirect costs are removed. The farmers also produce more income per hectare than the estate.

Several factors contribute to this difference in performance, but the biggest reason is that farmers are producing more per dollar spent on variable costs. Another factor that has led to lower yields at the core estate is that communal laborers seek employment with the settler farmers before seeking employment at the core estate. In addition, the farmers are given preference in land preparation and in establishing their crops over the estate.

Analysis of the two sets of budgets indicate that settler farmers and the core estate are both producing economically since they are able to cover their variable costs and yet retain a surplus that can be used to pay for the indirect costs (overhead). The farmers have been able to generate a relatively high income, which has acted as an incentive to increase production and to effectively use scarce resources.

3. Labor Use, Labor Availability, and Plot Size

The calendar of budgeted labor requirements for the Tsovane Estate for the 1986/87 crop year is presented in Table 10.

The average settlers used slightly more labor intensive methods than those used on estate lands, and there is some evidence that settler field operations are, on average, more timely than estate field operations. This may be one of the reasons why average settler yields are slightly higher than average estate yields.

Settlers reported that most families have four members who work in the fields and that family labor can usually perform the field work that needs to be done -- except during harvest, when a considerable amount of wage labor is hired. Another exception to reliance on family labor occurs when settlers must irrigate during school days. In such cases, the settlers usually need to hire additional help.

The peak labor requirement during January and February for cotton is budgeted at 16.7 labor days on the estate. Using this number as a basis for comparison, it appears that settlers should be able to successfully cultivate 3-ha plots, and perhaps 4-ha plots, by relying

Table 10. Tsovane estate budgeted labor days, requirements per ha.

Summer	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
Regular	3.6	3.6	3.6	3.6	3.6	3.6	3.6		25.2
Casual	1.3	5.5	13.1	13.1	2.6	1.3	1.1		38.0
Contract* (kg)				130	1248	956	875	292	3500

Winter	May	Jun	Jul	Aug	Sep	Total
Wheat						
regular	2.2	2.2	2.2	2.2		8.8
casual	.6	6.3	6.3	6.3	3.2	22.7
Beans						
regular	6.3	6.3	6.3	6.3		25.2
casual	2.7	10.6	10.6	10.6	5.4	39.9
contract*				13.0	13.0	26.0

*Harvest labor is paid $.06/kg of cotton picked.

almost entirely on family labor (except during cotton harvest when additional labor must be hired on contract). Family labor should be adequate to satisfy labor requirements for 4 ha of wheat, although additional labor is hired on the day when the wheat is combined. With a plot size of 5 ha, the average settler would be required to hire non-family labor regularly to produce the level of yields found on Tsovane.

4. Plot Size, Income Levels, and Repayment Capacity

Irrigation development in Zimbabwe can be used to help achieve three objectives: 1) put more people on the land, 2) provide increased income for farm families, and 3) generate new wealth that can be used to pay the irrigation operation and management costs and to repay at least some of the investment costs. The problem with using irrigation development to accomplish these purposes is that achieving one of these objectives can make it difficult to achieve the other objectives. Conflicts between these three objectives can be illustrated using data and information from the 1985/86 crop year for settlers on the Tsovane irrigation scheme.

The income cost, and related data for the 34, 2-ha, settler plots for the 1985-86 crop year are presented in Table 11. Crop budgets developed using average actual variable costs indicate that a reasonable average variable cost for each plot is $3,360. In Table 11, the variable costs were assumed to be the same for all settlers. The settlers all use the same technology and the same level of purchased inputs, except for hired labor. Those plots with lower cotton yields would probably have lower than average hired labor costs, but hired labor only accounts for about 8 percent of total variable costs.

The variation in income is associated with differences in yield. While there are some soil differences within the settler portion of

Tsovane, most of the differences in yield are associated with variability in management. The variability in yield is reflected in the different levels of gross margins for the different plots.

Income Levels and Repayment Capacity. Settlers generate non-cash income in the form of vegetable production from their irrigated, 150-m^2 garden. The cash income goal for farmers on ARDA schemes is at least 200 percent of the 1983 Universal Poverty Datum Line (UPDL) of $140/month or $1,680/year. The objective is to specify a plot size on ARDA schemes that will permit settler families to have a cash income of at least $3,360 per year. For all practical purposes, the settler families on Tsovane earn all of their farm-generated income from their 2-ha plot. On average, ARDA has effective achieved its objective of obtaining incomes equal to 200 percent of UPDL, since the average gross margin was $3,148 (Table 11).

Seventeen of the settlers had incomes in 1985-86 of more than 200 percent of the UPDL, and only five settlers had incomes of less than the UPDL ($1,680). Only the 17 settlers who had gross margins of greater than 200 percent of the UPDL would be capable of simultaneously achieving the ARDA income objective and having any repayment capacity.

Allocation of Economic Rent. The real world involves much more complexity and many more alternatives than discussed here. Our purpose in this analysis is not to reflect reality, but rather to highlight significant issues and alternative ways of dealing with the issues.

Tsovane farmers demonstrated during the 1985-86 crop year that they are capable of generating "economic rent." That is, Tsovane farmers are capable of generating income in excess of the income needed to keep the "variable" resources (such as fertilizer and hired labor) involved in the production process. In operational terms, the costs of those variable resources which have alternative uses during the crop year are treated as variable costs in the crop budget. The gross margin from the crop budgets can then be treated as a proxy for the economic rent, which can be allocated to the "fixed" resources in order to keep those resources in the production process over the long run. The major categories of fixed resources are family labor and management, as well as the resources that constitute the Tsovane irrigation scheme.

In the short run, the family and scheme resources can be considered to be fixed resources; that is, it is assumed that they will not be used for purposes other than producing agricultural goods in the short run. The variable costs associated with using the fixed resources can be considered to be zero, since there is essentially no alternative use for fixed resources in the short run. For purposes of discussion, the Tsovane irrigation scheme and the unpaid settler family labor and management are considered fixed resources.

From the standpoint of the Tsovane settlers, the long-run costs associated with the irrigation scheme are the recurring costs in excess of the $120 already paid by the settlers which are associated with operating and managing the scheme, and investment costs. The ability of production in the scheme to keep the scheme resources and the settlers' labor and management resources committed to the production process over the long run depends on the amount of economic rent generated and the way in which that rent is allocated among the different sets of fixed resources (Repetto, 1986).

Table 11. Gross margin for Tsovane settler plots (1985-86 crop year).*

Plot #	Income/ha wheat	Income/ha cotton	Income/ 2-ha Plot	Var. Cost/ 2-ha Plot	Gross Margin/ Plot	% of 200% of UPDL**
	-------	-------	-----$-----	-------	-------	
1	1,288	2,997	8,570	3,926	4,644	138
2	1,256	2,876	8,264	3,926	4,338	129
3	825	1,782	5,214	3,926	1,288	38
4	1,013	1,918	5,862	3,926	1,936	58
5	806	2,693	6,998	3,926	3,072	91
6	852	3,122	7,948	3,926	4,022	120
7	879	3,058	7,874	3,926	3,948	118
8	795	2,406	6,402	3,926	2,476	74
9	1,040	2,924	7,928	3,926	4,002	119
10	879	3,058	7,874	3,926	3,948	118
11	1,175	2,763	7,876	3,926	3,950	118
12	1,228	3,304	9,064	3,926	5,138	153
13	1,094	2,506	7,200	3,926	3,274	97
14	633	2,789	6,844	3,926	2,918	87
15	208	2,053	4,522	3,926	596	18
16	287	2,420	5,414	3,926	1,488	44
17	610	2,746	6,712	3,926	2,786	83
18	798	2,896	7,388	3,926	3,462	103
19	798	2,931	7,458	3,926	3,532	105
20	1,013	3,001	8,028	3,926	4,102	122
21	717	2,829	7,092	3,926	3,166	94
22	906	2,875	7,562	3,926	3,636	108
23	1,256	2,654	7,820	3,926	3,894	116
24	952	2,790	7,484	3,926	3,558	106
25	1,309	2,684	7,986	3,926	4,060	121
26	1,450	3,349	9,598	3,926	5,672	169
27	1,253	3,041	8,588	3,926	4,662	139
28	909	2,509	6,836	3,926	2,910	87
29	1,018	2,332	6,700	3,926	2,774	83
30	526	1,795	4,642	3,926	716	21
31	585	2,646	6,462	3,926	2,536	75
32	556	2,531	6,174	3,926	2,248	67
33	340	1,625	3,930	3,926	4	0
34	206	2,891	6,194	3,926	2,268	68
Average	866	2,670	7,074	3,926	3,148	94

*In Zimbabwe dollars.
**200 percent of the UPDL is $3,360.

The ability of a Tsovane settler to pay for operation and maintenance costs, in addition to the $120 already paid to ARDA during the 1985/86 crop year, depends on the economic rent the settler family can generate and how that economic rent is to be allocated between the family's human resources and the resources embodied in an effective irrigation scheme. In this document, it is assumed that at least $3,360 of the economic rent is allocated to the settler family income. Because of variability in settler incomes, which can be found on all schemes, the income objective needs to be stated in some detail if it is to serve as a guideline for irrigation development.

Income variability on the Tsovane scheme is probably considerably less than normal because the Tsovane settlement officer appears to effectively aid the settlers in terms of helping them acquire credit, making timely purchases of inputs such as fertilizer and seed, and helping settlers market their crops.

The interactions among repayment capacity, plot size, and management is illustrated in Table 12. "Subsistence management" is based on the average gross margins per hectare for the 11 settlers with the lowest gross margins for the 1985-86 crop year. "Average management" is based on the average gross margins for all settlers. "Preferred management" is based on the average gross margins for the 11 settlers with the highest gross margins.

Table 12. Economic rent and payment capacity: the impact of plot size and level of management when acceptable settler income is set at $3,360 (Tsovane).

Plot Size (ha)	Econ. Rent Subsist. Mgmt.	Pmt. Capac. /Plot	Econ. Rent Average Mgmt.	Pmt. Capac. /Plot	Econ. Rent Preferred Mgmt.	Pmt. Capac. /Plot
	-------------	-------------	-------------	$*	-------------	-------------
1.0	833	(2,527)	1,574	(1,786)	2,206	(1,154)
2.0	1,666	(1,694)	3,148	(212)	4,412	1,052
3.0	2,500	(860)	4,722	1,362	6,618	3,258
4.0	3,333	(27)	6,296	2,936	8,824	5,464
5.0	4,166	806	7,870	4,510	11,030	7,670

*In Zimbabwe dollars.

From Table 12, it can be seen that settlers who had "preferred" management would have a repayment capacity of $1,052/ha on 2-ha plots. If the payment level for all settlers was set at $1,052/ha, nine of the settlers would have had family incomes below the poverty level ($1,680) and three settlers would have had negative family incomes in 1985-86. Settlers with "average" and "subsistence" management would have no payment capacity if the income objective were to take precedence. Yet, it would not be practical to base repayment schedules on individual ability to pay, for this would eliminate the incentive settlers have to generate high economic rents. Therefore, it is necessary to rely on a single payment level for all individuals, although the payment per hectare could be increased as the plot size increased.

As indicated in Table 12, the low incomes of the nine settlers could be increased by increasing their plot size or their management skills. If plot size were increased, the number of settlers at Tsovane would have to decrease -- an alternative generally regarded as very undesirable in communal areas in Zimbabwe. Note that when the management skill is at subsistence, repayment is negative, even at plot sizes of 4.0 ha (Table 12). Income objectives for settlers with this level of management skill cannot be achieved. Therefore, programs that will improve the management skills of settlers can significantly affect whether or not the objectives of obtaining adequate family incomes and repayment capacities can be achieved.

The relationship in Table 12 between the number of settlers on Tsovane and the repayment capacity at three levels of management when the income objective is set at $3,360 are depicted graphically in Figure 2. It appears that if plot size were increased to 3 ha, and if a program were implemented to improve the management skills of the Tsovane settlers who are currently poor managers, it would be possible to implement a repayment schedule. Could such a schedule call for payments large enough to cover all O&M and investment costs? The answer to that question depends on the magnitude of the investment and the O&M costs and the level of unallocated economic rent.

The feasible level of investment for different levels of annual O&M costs, different plot sizes, and two levels of management are presented in Figure 3. In this example, it was assumed that the life span of the original investment would be 20 years with no salvage value, and with an interest rate of 12 percent. A negative level of feasible investment (e.g., for "average" management skills and 2-ha plots) is used to indicate that investment is not financially feasible because no economic rent is available to repay investment costs. The feasible level of investment is greatly influenced by the level of settler management and plot size, but somewhat less by the level of annual O&M costs.

This information should be used in one of two ways. First, necessary investment and O&M costs could be estimated. Then, it could be determined whether or not it would be feasible to generate the level of economic rent needed to justify such costs. Second, the expected level of economic rent could be estimated. Then, it would be determined whether or not it would be possible to set feasible O&M and investment costs which fit within the economic rent available. Both O&M and investment costs compete for the economic rent that could be allocated to settler family income. The strength of this competition depends on the plot size established and the level of settler management skill allowed to develop. Large plot size, which increases repayment capacity, directly affects the number of settlers that can be placed on an irrigation scheme. For the $10,654 investment cost per hectare (from page 38) to be economically justified, 4.0-ha plots would be required on the scheme, along with "preferred" management skills, as can be seen in Figure 3.

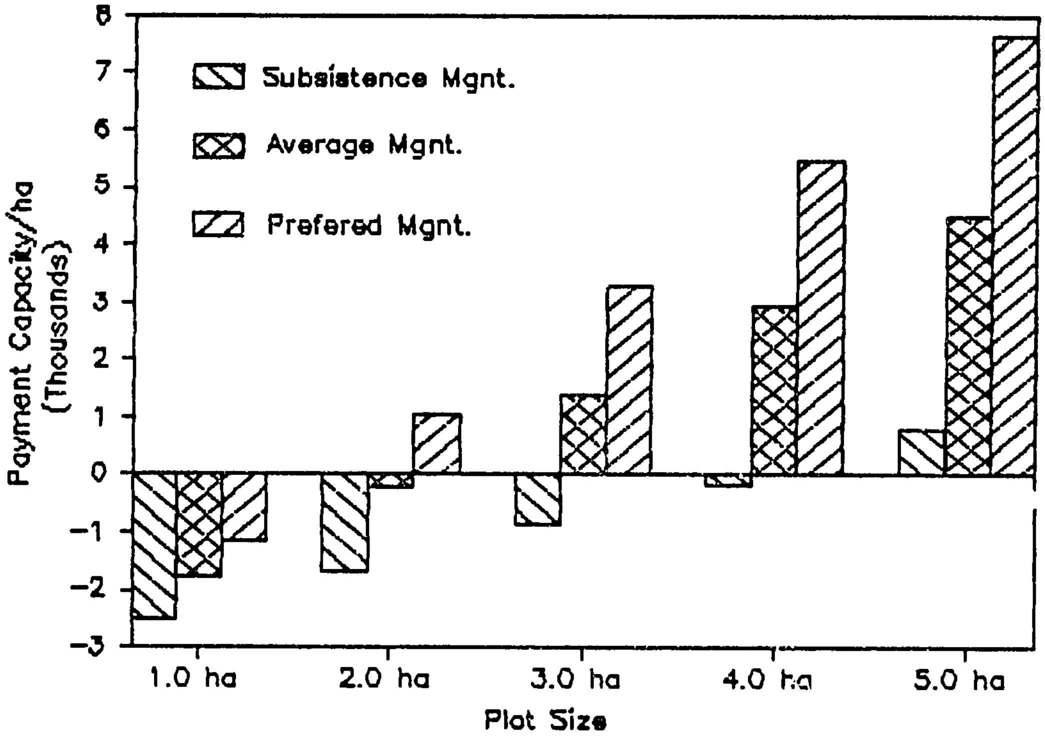


Figure 2. Payment capacity as influenced by management capacity and plot size (Tsovane).

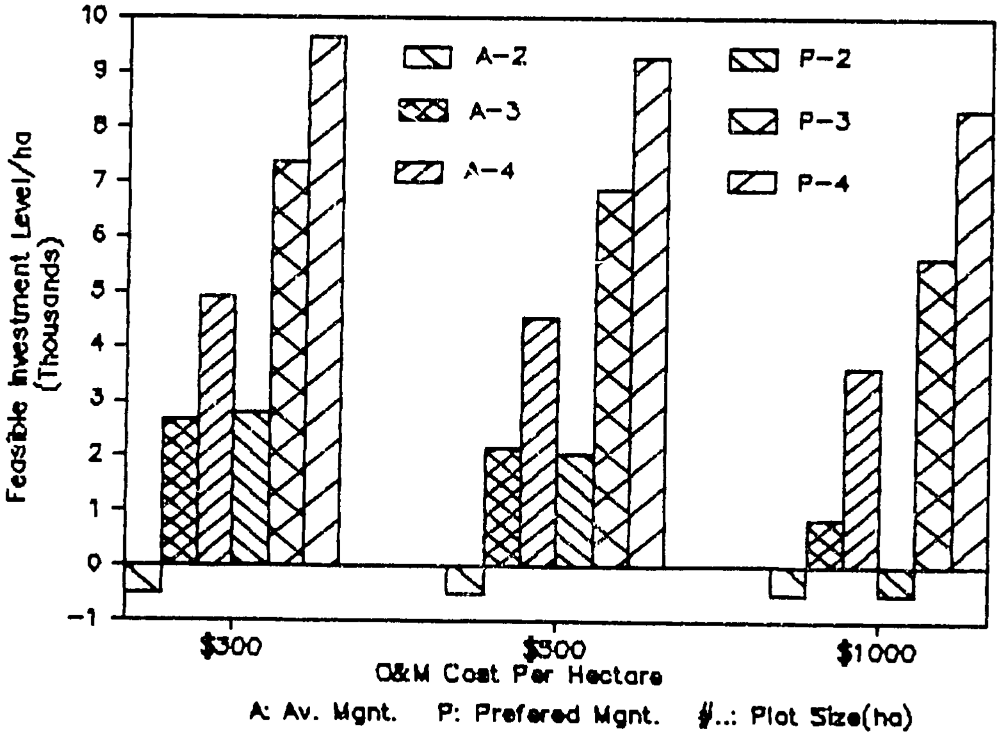


Figure 3. Feasible level of investments on Tsovane (influenced by O&M, management and plot size).

Conclusion. The information from the Tsovane scheme used above indicates some of the difficulties in using irrigation development as a means of economic development. Most economic development programs that rely on irrigation have multiple objectives: 1) place as many people as possible on the land, 2) provide the opportunity for settlers to earn an acceptable level of family income, and 3) have the development be capable of repaying the public costs involved.

As the presentation above indicates, there are inherent conflicts in simultaneously achieving these objectives. This does not mean that irrigation development cannot be an effective means of economic development, but it does show the importance of establishing an acceptable compromise among these objectives before irrigation development takes place. It is not surprising that the "comma hectare" schemes (schemes which have plot sizes of .1 to .9 ha) found in many communal areas in Zimbabwe have at best limited and, in most cases, no repayment capacity. The information from Tsovane demonstrates the importance of establishing a reasonable set of objectives prior to planning irrigation development if the potential for irrigation development to effectively contribute to economic development is to be realized.

5. Value of Water

While there are many procedures for allocating economic rent (gross margins are used as a proxy for economic rent in this report), one widely used procedure is to allocate a portion of the economic rent to the irrigation water, expressed as "water has a value of $X/1000 m^3." Information in this form is particularly useful for gaining a better understanding of water resource policies. Such information is also useful for developing guidelines for micro-issues, such as the feasible level of investment in the development and improvement of irrigation schemes.

The same type of problem exists in allocating economic rent between water and other claimants as exist in allocating economic rent between family labor and management and the resources of the irrigation scheme. The general discussion of these important issues is not repeated here, but the central issue of deciding the reward given to family labor and management in order to meet family income objectives established by society must be dealt with.

If it is decided that economic rent will first be allocated to meet the $3,360 family income objective, no economic rent remains for allocation to water on 2-ha plots with "subsistence" and "average" management. This implies that water used on Tsovane will have no value (Table 12). If, however, the opportunity cost of family labor is regarded as a value that must be reimbursed to determine the value of irrigation development and improvement from a social or macro-economic standpoint, the water provided to settlers probably has considerable value. If the settler labor would be unemployed if it were not utilized on Tsovane, the social opportunity cost of the settler labor would be zero and all of the economic rent could be allocated to the value of water.

For purposes of discussion, it is assumed that the opportunity cost to society of using settler labor on Tsovane is $1,200 each year for the labor used on a 2-ha plot. The proxy used for economic rent is $3,190 for a 2-ha plot. The value of the water used on a 2-ha plot would then be $1,990 or $995/ha. The average amount of water pumped per hectare on Tsovane is 11,000 m^3 each season, or 22,000 m^3 each year. The average value per 1,000 m^3 of water would then be $45.23. These values are "average" values of water. It would be better if the economic analysis was based on the "marginal" value of water, but information on marginal value could not be obtained. Remember that the use of average values in the analysis below is a simplification, and sometimes this simplification can lead to errors.

While there are many ways to use this information, only three possible uses are discussed here: a) to determine the feasibility of rehabilitation and improvement programs, b) to determine the feasibility of new development programs, and c) to establish thresholds for yield increases required to justify irrigation development or improvement. All three uses involve the development of rapid appraisal guidelines.

<u>To Determine the Feasibility of a Rehabilitation or Improvement Program</u>. Suppose an improvement program proposed lining a section of canal that would decrease the required pumping per hectare from 20,000 m^3 to 16,000 m^3 with no change in yields or other inputs. The value per 1,000 m^3 of water would increase from $49.75 to $62.19 per 1,000 m^3. Therefore, the cost each year of saving water could be up to $12.44 for every 1,000 m^3 of water "saved." If the improvement lasted for 20 years, involved no O&M cost, and the appropriate discount rate was 13 percent, up to $87.39 could be invested for each 1,000 m^3 of water saved.

<u>To Determine the Feasibility of a New Development Program</u>. If water in a particular region of the country had a known value ($35/1,000 m^3, for example), this information could be used as the basis for the preliminary analysis of a proposed scheme development. If the proposed scheme required an estimated field delivery of 16,000 m^3/ha each year, and the expected conveyance efficiency was 55 percent, 29,090 m^3 would have to be diverted or pumped in the scheme. The first rough estimate of the expected economic rent per hectare would be $1,018 ($35 x 29.09). If $200/ha each year were allocated for O&M costs, $818 would be available to repay investment costs. If the expected life of the scheme was 20 years with no salvage value, and an interest rate of 13 percent was used, the initial investment could be as high as $5,746/ha. If the expected investment costs were $10,000/ha, and if the objective was to develop only those schemes that demonstrated economic feasibility, and this scheme would probably not be investigated further. However, if the expected investment costs were $5,000/ha, the potential scheme should probably be investigated in

greater detail.

To Establish Thresholds for Yield Increases. Agronomists often develop guidelines to indicate the yield increases that could be expected with the application of additional water. In the early stages of evaluating a potential improvement program, information about expected yield increases and the crop value can be paired with information about the value of water to see if further investigation of the proposed improvement program is justified.

If information about the value per 1,000 m^3 is available for a number of irrigation schemes, decision-makers begin to gain a better understanding about what makes a scheme economically feasible and are better able to estimate the level of subsidy that would be required to develop a scheme that was not economically feasible. Such information is rough, but it can be the basis for better decisions about proposed irrigation development and improvement programs.

6. Conclusion

From a financial standpoint, Tsovane is an expensive scheme (investment costs exceed $10,000/ha). However, it is also a productive scheme. In 1985-86, nearly $500,000 of gross margins were generated ($332,686 from the 270-ha estate and $157,610 from the 68 ha farmed by settlers). Gross margins of $500,000 mean incomes exceeded variable financial costs by about $500,000. This is the "economic rent" generated by the scheme.

The issue then becomes how to allocate this "rent" among 1) repayment of capital costs, 2) repayment of other non-reimbursed ARDA costs, and 3) payment to family labor and management. This "rent" would amount to $1,479/ha for each of the 338 ha, or about $3,000 for a 2-ha plot.

If meeting family income was the primary objective ($3,360 at twice the UPDL), there would be no "rent" to allocate for repayment of capital costs and other non-reimbursed ARDA costs. It would be possible to reimburse a portion of these costs by increasing the size of the settler plot, by increasing the management skills of the settlers, or both. Unless this were done, turning the scheme over to the farmers would not be financially feasible. If the income objective is taken seriously, the objective of turning the financial responsibility of the scheme over to the settlers, and the implied objective of getting as many farmers as possible on the scheme by holding the plot size to 2 ha, directly conflict. As indicated in Figure 2, plot size would have to be 4.0 ha and settlers would have to have a high level of management skills (the "preferred" level of management) for settlers to come close to being able to pay both capital and O&M costs.

G. SYSTEM STRENGTHS AND WEAKNESSES

1. Strengths

System Condition. The system is new (two years old) and is well managed. Most operators seem to work according to project document definition.

Scheme Personnel. The scheme has able personnel. The estate manager is able and works well with the settlement officer (in charge of settler scheme extension) in monitoring and evaluating settler farmers' performance.

Water Supply. There is an adequate and reliable water supply from the Save River through the water right of Chisumbanje Estates. There are also contingency measures for obtaining water in the dry season in the form of extra water allocation through the Regional Water Authority.

Agronomic Factors. Agronomic practices, based on scientific recommendations, have been readily adopted by settler farmers and have resulted in wheat and cotton yields that are comparable to experiment station yields. The high adoption rate is due to the strict discipline that ARDA demands.

System Canal Design. The canal is designed to take advantage of some of the soil properties in the scheme. For example, canals in the black basalt soils are unlined to take advantage of their shrinking and swelling characteristics.

Data. Good data are available on costs of production on both the estate and settler schemes.

Higher Income Gains. Settler farmers have realized more income gains in two years than most similar schemes in the same time frame. Settler farmers out-produce the core estate per unit area, and they are more efficient utilizers of labor.

Cooperation. There is good cooperation among farmers, who have trust and confidence in the settlement extension officer.

Canal Maintenance. Canals on the settler schemes are well maintained and seem to be in much better functional condition than most core estate canals, especially those canals fartherest from the main road.

2. Weaknesses

Flow Measuring Devices. There are no flow measuring devices at the pump station and the storage dam (i.e., flow meters and staff gauges). The estate management personnel could use such devices.

Vulnerability of the System. The system's reliability depends, among other things, on the availability of critical spare parts (such as bearings -- which, at the time of evaluation, were not available in the country). Continued lack of vital spare parts will render the system unreliable and disfunctional.

Land Use. Selective allocation of land area to meet specific crop rooting depths would result in increases in yield. The agronomic evaluation of the lands on the South Block indicate shallow depth to bedrock and other subsoil problems.

Field Condition. Greater attention should be paid to land leveling and furrow alignment to facilitate even distribution of water to the crop.

Housing. Settlers think housing is inadequate.

AFC Payments. Farmers are unhappy about the delays by the AFC office in processing their earnings return after loan payments.

Future Development. Farmers are unclear about the future developments on the scheme (i.e., the planned phasing out of ARDA involvement on the scheme). Farmers are also unclear about issues relating to land tenure.

III. MUTEMA IRRIGATION SCHEME

A. INTRODUCTION

The Mutema irrigation scheme is in the Mutema Communal Area in Chipinge District. It is about 165 km south of Mutare, 45 km from Chipinge, and 25 km from Birchenough Bridge. Access to the scheme from the three major tarred roads is by all-weather gravel roads.

The scheme was first developed as a gravity system by the local people in 1928 and comprised the present two blocks along the Tanganda River near the take-off point of the main canal. The scheme was extended during 1952 to 1961. Figure 4 shows the current arrangement of the system. In 1973, sprinkler irrigation was introduced to overcome problems partly caused by the inadequate water supply from the Tanganda River (particularly during winter) and partly by the sandy soil in Block 1.

The gazetted area of the scheme is 520 ha with the actual developed area being 237.2 ha. The developed area is divided as follows:

Block 1 (sprinkler system)	-- 90 ha
Block 2 (sprinkler system)	-- 93 ha
Block 3 (surface system)	-- 54.2 ha

The scheme is located in agro-ecological region 5, which is characterized by low and erratic and annual rainfall (400 mm) and very high annual evaporation (2,080 mm). The area is suited to an extensive system of farming based mainly on livestock production.

The soils are derived from colluvium and alluvium. These vary from deep, permeable, coarse loamy sand in Block 1 to fairly deep sandy loam to sandy clay loam in blocks 2 and 3.

The water supply for the gravity irrigation system (Block 3) is from the Tanganda River. The water supply is based on a continuous flow after satisfying the Middle Save estate irrigation water requirements during the dry months. The sprinkler system is fed from four tubewells located along the bank of the Tanganda River.

The original objective of the scheme appeared to be food production to reduce the risk of famine, since harvest yields above subsistence levels were experienced only once in 5-6 years in this region. The Government objectives for Mutema now specify that Mutema is to be a source of grain for food deficit areas and that it create employment and income. The objectives include other socio-political goals.

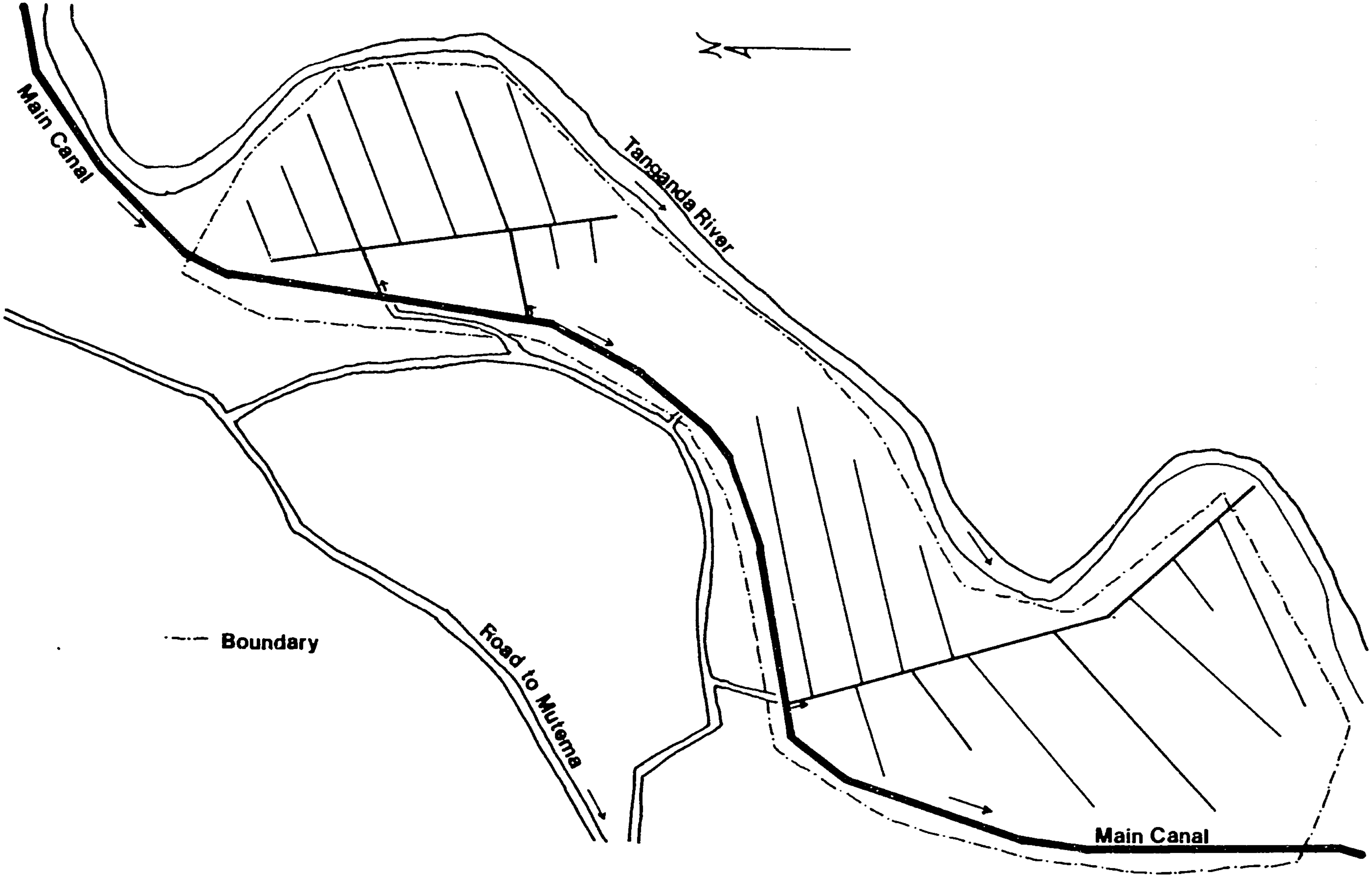


Figure 4. Current arrangement of Mutema scheme.

B. THE PHYSICAL SYSTEM

1. Hydrology

The Tanganda River supplies water to Block 3 of the scheme. The intake has a design discharge of 120 L/s, though the actual discharge measured at the intake point was 93.3 L/s. A large amount of sand is deposited in the main canal. This reduces the conveyance capacity of the canal and requires a full-time labor force to clean the head reaches of the canal. Constructing a desanding structure at the intake might solve this problem. The feasibility of this solution would depend on an economic comparison of the labor effort and the cost of construction.

Four tubewells along the Tanganda River provide water for blocks 1 and 2. The groundwater is pumped, using four Sangus pumps, into the main pipeline which serves the sprinkler systems.

The amount of water available for sprinkler irrigation did not seem limited, even during the dry winter season. On the other hand, the Tanganda flow is either considerably reduced or stopped entirely during the dry season. In the dry season, water is supplemented from the ARDA conveyance canal going to the Middle Save estate for Block 3. Even so, Block 3 suffers from severe water shortage.

The water right for the gravity section is 7 L/s in 24 hours. The upper limitation of flow from the tube wells is not fixed. However, with all pumps working, the design supply is 192 L/s.

2. Soils

Two major soil groups occur in the scheme. One group consists of medium-textured soils which formed in colluvial, or slopewash materials from surrounding hills (siliaceous granite, quartzite and sandstone). Typically, these soils have a sandy loam surface layer with clay loam subsoils. Gravel and cobble occur below depths of 60 cm in some soils, particularly those close to the hills. Soil reaction is slightly to strongly acid (pH 6.5 to 5.2). The cation exchange capacity is usually below 30 milli-equivalents/L, and the base saturation is well above 80 percent. Fertility is low to moderate. The available water capacity is about 10 percent, the infiltration rate is moderate, and permeability is moderate. In one field, a water table was observed at 120 cm. Deeper augering was precluded by gravel. These soils are predominant in Block 3.

The other major group consists of deep, medium- to coarse-textured soils which were formed in alluvium. Typically, these soils have little visible development and are moderately leached. Due to fluvial distribution, the soils in Block 1 are predominantly loamy coarse sands, while the soils in Block 2 are primarily sandy clay loams and clay loams. In Block 1, the sandy textures result in low available water (4 percent), very rapid infiltration rates (300 mm/h), and low fertility. Soil reaction is neutral to slightly alkaline (pH 7.3 to 7.7).

By contrast, the soils in Block 2 typically have loam surface layers underlain by clay loam or sandy clay loam subsoils to about 85 cm. The deeper substrata consist of contrasting layers of alluvium which range in texture from clay loam to loamy coarse sands. Soil reaction is neutral to slightly alkaline (pH 7.3 to 7.6), and carbonate accumulation below 150 cm is common. Base saturation and cation exchange capacity are high, and the fertility status is moderate. The available water capacity is about 10 percent (to 100 cm) and the infiltration rate is moderate.

In summary, the soils in Block 2 are probably the most productive due to better fertility and higher available water, and are best suited for sustained irrigation without special management problems.

Soils in Block 3 can be similarly productive if recommended fertilizer use is maintained and if water availability is assured. They are well suited for irrigation without major management problems.

Conversely, the soils in Block 1 are the least productive due to their sandy nature. This land requires more frequent applications of water and fertilizer (manuring would be recommended) and a generally higher level of management. Their ability to sustain long-term irrigation is limited by these constraints. A soil survey that specifically refers to the suitability of land for irrigation should be included as part of any rehabilitation program on this scheme.

3. The Physical System

Prior to 1973, the Mutema Irrigation System was surface irrigated. Because the water supply was unsatisfactory, part of the area was converted to sprinkler irrigation. Currently Blocks 1 and 2 are sprinkler irrigated and Block 3 is surface irrigated.

The water diverted from the Tanganda River to Block 3 is conveyed initially in a 0.9 km lined canal through an area of sandy soil. The canal lining has deteriorated, and there are significant losses due to seepage.

After the lined section is a 2.73 km section of unlined canal though an area of heavier textured soils. While the losses per unit length of unlined canal are lower than those for the lined canal, they are not negligible (see page 65).

Water is distributed to two areas of Block 3 through two unlined submain "furrow" canals that are 2.0 km and 1.6 km in length. In addition, there are two unused night storage dams on the canal system, neither of which are capable of holding water for any length of time.

At the field level, water is applied to border strips 3-4 m wide and 75-100 m long. Siphons are used to apply water in one part of the scheme, while in the remaining areas, water is diverted to field ditches and released to each plot through bank cuts. The distribution system in the surface irrigated area is in generally poor condition with high seepage losses.

The sprinkler-irrigated area is supplied with water pumped from an aquifer at a depth of approximately 10 m. There are four electrically driven, axial flow pumps linked together by an asbestos cement supply line. Details of the pump operation are given in Table 13.

Table 13. Pump operation at Mutema.

Pump	Power Required (kW)	Output (L/s)	Supply Pressure (KPa)	RPM	H (m)
1	42	30	600	1462	56
2	22	20	-	2900	30
3	112	85	445	1464	150
4	56	57	620	1456	75

Pump 2 was not operational due to bearing failure, and has been inactive for a least a year. Regular maintenance of the pumps appears to be a problem. A preliminary test of pump 1 showed that the flow was as designed: 30 L/s. Assuming that pumps 3 and 4 were operating as designed, the current flow available would be 172 L/s. A check of the water quality delivered from pump 4 showed that the water was saline. However, the other wells had good quality water.

The water is supplied to the fields through 8.2 km of asbestos cement pipe. There are no obvious problems with the distribution system and the pipes are assumed to be in good condition. At the field level, the main lines have hydrants every 90 m. Significant leakage was observed at the hydrants.

Water is distributed through aluminum laterals 180 m long and 76 mm in diameter. The laterals are in sections 6 m long and have 15 sprinklers per lateral spaced every 12 m with risers 1.5 m high. The system design requires 27 laterals, but only 14 were operational; when the system was inspected, only 9 were in use.

The sprinkler performance was extremely poor, with high losses due to leakage at pipe joints and uneven distribution due to sprinkler malfunction and low operating pressures. The sprinkler system is performing at levels substantially below that considered adequate.

4. Resource Conservation

High salinity is a problem on about 10 ha in the northeastern section of Block 2, and this area has been abandoned. The salinity is most likely related to shallow depth to bedrock, lack of adequate drainage, and a high water table. A surface soil sample taken from an abandoned field had an electrical conductivity of 30 dS/m, and the pH of the saturated paste extract was 7.6.

Severe soil erosion is evident in the village areas. As a result of extreme overgrazing, rainfall from heavy storms has removed productive topsoil, impacted soil structure, and created vast gullies, some up to 1.5 m deep. The heavy runoff contributes significantly to siltation of the surface water system.

C. SOCIAL/INSTITUTIONAL SYSTEM

1. Social Structure

Despite problems with the scheme, Mutema farmers are glad that there is irrigation in their area. A farmer stated that "Mutema saved us from starvation."

To be chosen to farm at Mutema, an individual must fulfill certain conditions. Among the most important selection criteria are the following. The applicant must:

1. Have Zimbabwean citizenship.
2. Be married with dependents (for labor supply).
3. Be under 50 years of age (though this is no longer strictly enforced).
4. Have irrigation experience.
5. Own cattle for draft power.

There are an estimated 300 people on the waiting list who wish to farm at Mutema.

Land. Land at Mutema belongs to AGRITEX, not to the farmers. The smallest plot at the scheme is about 0.2 ha and the largest is 2.0 ha. The average plot size appears to be between 0.5-1.0 ha. AGRITEX statistics show the following plot-size distribution (Table 14).

Table 14. Plot size distribution at Mutema, according to AGRITEX.

Plot Size (ha)	% of Farmers
0.1 - 0.4	26.0
0.4 - 1.0	74.0
More than 1.0	0.3

Our study showed that there are more larger farmers (above 1.0 ha) than indicated in the above table. Although we have no statistics to confirm this, some farmers claimed that a greater proportion of larger plots (1.0-2.0 ha) were under sprinkler irrigation, while most of the smaller plots (less than 1.0 ha) were under surface irrigation.

One farmer claimed that originally AGRITEX did not control enough land to give everyone 2.0 ha, so many farmers received less. Other farmers indicated that when plotholders originally came to Mutema, all could not afford to pay the "maintenance fee" of $145/ha/year. Some also felt they could not afford to buy sufficient inputs for a hectare of land. These farmers, therefore, received less than 1 ha. Some female farmers claimed that four categories of farmers received the 2- ha plots: (1) relatives of the chief, (2) very good farmers, (3) farmers able to pay the full maintenance fee, and (4) those farmers with big families.

Although technically the land belongs to AGRITEX and cannot be inherited, in practice AGRITEX staff allow family members to continue farming the land after the original plotholder dies. This is particularly true in the case of good farmers.

Additionally, although a plotholder may only farm 1 ha, he may have an extensive family at Mutema, each member farming 1 ha; the family, in essence, controls more than 2 ha. Thus, if two brothers each farm a 2-ha plot and one brother dies, the second brother can "inherit" his brother's land and control 4 ha.

AGRITEX staff said that it is not possible to formally increase the size of plotholders' farms. Many people are waiting to come to Mutema, and second generation farmers must be considered.

One farmer did mention that he is able to farm more land by "renting" small parcels from plotholders who cannot, or will not, pay the $145/ha/yr maintenance fee. This farmer said he pays the maintenance fee and the other plotholder allows him to farm that land. Though not formally recognized, such an arrangement effectively increases the size of a farmer's holding.

AGRITEX staff said that they could, and have, evicted farmers from the scheme if they have not performed properly. Eviction is a last resort, however, after the extension staff has worked closely with the farmer. AGRITEX staff predicted that this would happen to some farmers this year. Additionally, a few farmers have given up farming their plots in the wet season due to poor soil conditions, inadequate irrigation, and drought.

Outside Interests. There was great variation in responses regarding how many plotholders continue to farm dryland outside Mutema. One source estimated that only 20 percent of plotholders farm outside Mutema; another thought that "most" did. It would be accurate to say that some plotholders continue to farm outside Mutema, though usually on unprofitable dryland plots.

There was also a variety of responses regarding how many Mutema plotholders are "pure" farmers and how many have other sources of income, such as businesses or teaching. A Mutema extension agent said that about 60 percent of the plotholders have non-farm income. The other 40 percent are usually older, and live only by farming. He also mentioned that those plotholders having outside income can usually afford more agricultural inputs and are therefore better farmers. Farmers, however, estimated that only 5-25 percent of plotholders have outside income. Farmers also reported that plotholders consider Mutema "home" and want to improve their lives there, and not outside Mutema.

Power. Most farmers reported that power at Mutema is still in the hands of traditional power holders, such as the chief, the sub-chief, and other relatives. An extension agent pointed out, however, that the chief's power is primarily centered on village or "home" matters. The irrigation management committee (IMC) seems to have power over irrigation matters. The IMC, of course, is constrained by AGRITEX rules. No one said they believed that power was a function of the amount of land owned; i.e., a farmer with 2.0 ha does not necessarily have more power than a farmer with 0.5 ha.

Women. A Mutema extension agent estimated that about 20 percent of the plotholders were female. He mentioned that some were better farmers than men, some were worse. Two female farmers interviewed could think only of one female plotholder farming a 2-ha plot.

The female farmer interviewed reported that women are actively engaged in system operation and maintenance, including opening and closing gates and maintaining canals. Other female farmers reported no discrimination against women, but said if they did experience discrimination, they would report it to the AGRITEX water bailiffs. They said that male farmers usually stay at Mutema, but that they often drink beer and leave the women to work in the field.

While at Mutema, we witnessed a "master farmer" training session organized by extension agents. At this session, approximately one-third of the participants were female.

2. Irrigation Management Committee

According to the chairman and vice chairman of the IMC, the committee's purpose is to settle disputes and collect the $145/ha/year maintenance fee from the plotholders. Other farmers described the IMC's purpose as to coordinate activities between farmers and AGRITEX, to monitor progress and trouble, to deal with "collective" rather than individual farmer problems, and to work with farmers to develop new procedures and ideas.

The IMC is composed of a chairman, vice-chairman, secretary, vice--secretary, treasurer, and two "members." These seven officers are elected at a yearly meeting. Farmers reported that all current officers are farmers and do not have significant non-farm income. AGRITEX staff members said that a very good farmer who has "security" against eviction would make a good committee member. Such a farmer would always be able to speak his mind.

The IMC makes decisions in consultation with the irrigation manager at Mutema, who has overall control of the scheme. Some AGRITEX staff suggested that the IMC is controlled by AGRITEX's irrigation manager. For example, the IMC consults with the manager if irrigation water is diverted to the wrong plots.

Some IMC members have received training specifically related to the committee's functions: leadership, bookkeeping, and government policy towards irrigation organizations. Some AGRITEX staff, however, complained that the training was not adequate and more training should be provided. Some farmers stated that the training was acceptable, but that the IMC members still could not answer the farmers' questions about irrigation matters.

The chairman of the IMC stated that the committee has instituted a $10 fine for farmers caught stealing water. He claimed that guilty farmers have paid these fines. If they are not paid, he said that the IMC and AGRITEX staff deny the farmer water. He further claimed that such farmers would eventually be evicted from the scheme. Though no farmers have been evicted from Mutema for water theft, the chairman said that some farmers have been evicted for not paying their yearly maintenance fee.

Almost all farmers contacted said that they were satisfied with the IMC's performance. Some stated that the IMC acts as a coordinating body between AGRITEX and the farmers. One plotholder said, however, that he preferred Mutema in the past before the IMC was formed, when only one person (the irrigation manager) was responsible and accountable. This farmer claimed that in the past, one visit to the manager could solve most problems.

Most farmers contacted felt that the IMC belonged to the plotholders, not to AGRITEX. A few farmers, however, stated that the IMC was a part of AGRITEX, which reflects some confusion in the IMC's objectives.

Problems. Some farmers felt that when the IMC was established, AGRITEX promised that the IMC would have sufficient power to carry out its functions. These farmers claim that the IMC does not have adequate power. The IMC, for instance, tries to supervise the water bailiff's work, but AGRITEX staff claim that the water bailiffs are responsible only to AGRITEX, who employs the bailiffs. Thus, these farmers say, the IMC cannot make the water controllers do a better job.

The IMC officers stated that "every day" they have problems. Plotholders constantly demand that the officers find spare parts for the broken pump and new pipes. The farmers get angry at the officers when the needed equipment, which is the responsibility of AGRITEX, does not appear. The farmers allegedly complain to the IMC officers: "Why don't you help the plotholders more?" Another farmer stated that IMC "fails" because it does not have control of the pipes.

A general problem is that the roles of AGRITEX and the IMC are not clearly spelled out. One farmer complained that AGRITEX staff always point accusing fingers at the IMC when something goes wrong and the IMC points accusing fingers at AGRITEX. The IMC officers also complain that they have to collect the maintenance fee from the plotholders, and the plotholders resent paying the fee. The officers claim that this makes the rest of their job difficult.

Suggestions for IMC Improvement. AGRITEX staff said that an ideal IMC would be able to "control farmers." Such an IMC would ask the farmers to clean a canal and the canal would be cleaned. Extension agents at Mutema said that a good IMC is based on trust and a desire for self-improvement. Furthermore, the extension agents said that such an IMC would be strong enough to enforce regulations. Some farmers stated that an ideal IMC would follow up on farmers' reasonable requests. For instance, if farmers asked the IMC to repair a broken fence, the fence would be repaired. A poor IMC would be one that contained many relatives from a single family as its officers and members.

The chairman and vice-chairman of the IMC did not feel that any drastic changes should be made within the IMC. They were satisfied with its current operation. They did say, however, that the three subcommittees dealing with tomato-canning contracts have more influence in the scheme than the IMC.

Some farmers felt that the IMC should be given more power. One plotholder said that currently, the IMC and the farmers are at the same level, and Mutema farmers state that the IMC "can't rule us." This plotholder complained that such attitudes lead to chaos. Other farmers claimed that AGRITEX was "closing" some farmers' rights. For instance, plotholders must pay the maintenance fee even if they don't receive water reliably. A stronger IMC, they reasoned, might stop this practice.

Other farmers said that the plotholders are ready and willing to take more control of the system. These farmers suggested that AGRITEX should do what AGRITEX does well: manage the main irrigation system and the physical structures. The farmers should do what the farmers do well: manage the farm irrigation systems. For the sprinkler system, AGRITEX should be in charge of the pumps, while the farmers should be in charge of the pipelines.

Having the IMC take control of the pipeline was a recurring theme. Some farmers felt that the IMC could manage the pipelines better than AGRITEX. One farmer pointed out that in the past the IMC received donations from farmers to maintain the pipes. These farmers believe that the IMC could manage new and functioning pipelines well, but that it is impossible to properly manage the current leaky pipelines.

The chairman and vice-chairman were asked if the IMC could manage the pipes if they were given 20 percent of the yearly maintenance fee ($145/ha/year) paid by the farmers to AGRITEX. The officers said that 20 percent would not be sufficient; only 100 percent of the maintenance fee would provide enough income to purchase new pipes. AGRITEX officials estimated that one new pipeline will cost about $3,400. Mutema needs a minimum of 15 new pipelines, and preferably 27.

D. CHARACTERISTICS AND PERFORMANCE OF SYSTEM MANAGEMENT

1. Water Supply, Allocation, and Distribution

Gravity System. A gravity canal runs from the Tanganda River and divides into two branch canals in Block 3. The total length of the canals is 7.24 km. The estimated canal capacity is between 150-160 L/s at the Middle Save take-off point. There are considerable water losses in both the lined and unlined sections of the main-canal. During the study, the flow at the intake was 93.4 L/s. The water losses in the lined and unlined sections were 1.0 percent/100 m and 4.7 percent/100 m of canal, respectively. The average water losses were 1.5 percent/100 m (52 percent) of canal for a total loss of 52 percent over the length of the canal.

The losses are due to lack of maintenance, uncontrolled weed growth, existence of illegal water abstraction, and different types of soil. The sandy soil justifies lining sections to field edge. The high water losses in the main canal have serious implications for water availability and reliability, especially in the dry season.

AGRITEX water bailiffs control water allocation to farmers by operating the canal gates where they exist. When the water supply is adequate, it is normal to allocate water on rotation. The irrigation interval is 10 to 12 days, and the bailiffs keep a record of the number of plots irrigated daily. However, because the gates have been vandalized and the locks removed, control is difficult. It is evident that no water schedule exists on the scheme. Due to different farmer cropping patterns, water allocation depends on the farmers' preferences and need for water and not on AGRITEX.

The field layout is complicated -- resembling a "jig-saw puzzle" -- due to steep border slopes (1.5 percent) and uneven field surfaces. Water is delivered from the branch canal into an unlined head ditch, which is blocked to divert water into the border strips. The water is continuously blocked in an attempt to ensure even distribution over the whole length of the border, but some (not quantified) amount of runoff was observed at the end of the field. This system is labor-intensive.

The average depth applied was 49 mm with a flow of 7 L/s (25.5 m^3/h), which results in a 69 percent field application efficiency. The calculated average water requirement for maize at hard-dough stage was 71 mm.

<u>Sprinkler System</u>. The four pumps deliver water into four main lines and a sub-main. There are two main lines in Block 1; the rest are in Block 2. The pumping plants are designed for a total capacity of 192 L/s, but capacity has been reduced to 172 L/s because pump 2 is not operating. The system is designed for 27 laterals (76 mm) delivering 26.4 m^3/h each and having a precipitation rate of 8.2 mm/h operating simultaneously. The net application depth is 65 mm with an 8-hour set-time at each lateral. The design irrigation interval for Block 1 is 6-9 days and for Block 2, 9-12 days.

The pumping test results based on pump 1 appear to indicate that the pump is operating near its rated output. It was assumed that the other two pumps operate at or near their given capacities.

The system currently operates on a three-lateral-set period per day, with less than half the required number of laterals. The laterals are moved to the other block when irrigation has been completed in one block. This has resulted in a cycle of more than 14 days. The recommended cycle, based on soil textures and crop water requirements, should be 5 days for Block 1 (sandy soils), and 8 days for Blocks 2 and 3 (sandy clay loam - clay loam soils).

Leakages at hydrant positions and on lateral lines at all joints were observed to be due to worn rubber seals and general wear of the system. The net effect is (1) sprinkler discharge is 30 percent below design requirement, (2) sprinkler operating pressure is, on average, 60 percent below design sprinkler operating pressure, and (3) overall system application efficiency is 30 percent. Based on our calculations, the system should apply 33 mm (gross) every 4 days for Block 1. The current evaluated practice applies 39 mm every 14 days, which means the system is applying less water than the crop requires.

2. Water Adequacy, Reliability, and Equity

Adequacy. Adequacy of water supply can be seen from two viewpoints: adequacy at the source and adequacy of field deliveries. The source for the tube wells is highly adequate. The aquifer is fed, not by the rivers, but from the outlying highlands, according to local sources. Even when all four pumps are pumping (192 L/s) the drawdown is negligible.

The adequacy of the Tanganda River flow for surface irrigation, however, depends on the season. In summer (October-March), the Tanganda flow is adequate to supply the needed amounts. In the winter, however, the flow is usually inadequate, and even supplementary water from the nearby ARDA canal may not change this.

The adequacy of field deliveries is variable. The worn sprinkler equipment leads to high conveyance losses and results in inadequate supplies at the field, since the irrigation intervals become too long.

Adequacy of field delivery to Block 3 (gravity system) is influenced strongly by seepage losses, which occur in both the lined and unlined parts of the main canal. The losses sometimes lead to inadequate field deliveries, especially in the low sections. In winter, this becomes accentuated due to the low flows in the Tanganda River.

Reliability and Equity. The reliability of groundwater supply to Block 1 and 2 is good. The groundwater supply is reliable, even in periods of extreme drought (i.e., 1982-84). However, reliability to the field greatly depends on management's control of lateral line shifts.

The flows for Block 3 (gravity) are generally reliable in summer, but highly variable in winter. In extreme years, there may be no flows at all.

Equity is not a problem in the sprinkler irrigated sections due to the relatively higher level of control associated with a pressurized system. In the gravity section, however, equity is a problem even in normal dry years during the winter season. Local sources claim that the tail sections of Block 3 have received no water at times. Lessened conveyance losses through good maintenance and a desanding structure at the intake might resolve this problem.

3. Farmer Involvement in Irrigation Management

Operation and Maintenance. In the flood irrigation of Block 3, the IMC does not have a great deal of irrigation decision-making power. Irrigation is done in sequence, turn by turn, and the informal schedules are made by AGRITEX staff and the water bailiffs. Some farmers said that the schedule is based on the stage of crop growth -- when the crop needs water, AGRITEX attempts to supply it.

The water bailiffs are supposed to open and close the gates and inform farmers when their irrigation water will arrive. The water bailiff also acts as a kind of water policeman; he is supposed to stop plotholders from stealing water out of turn. If he catches violators, he is to have them pay a fine to the IMC. The water bailiffs also have plots of land at Mutema, even though they are employees of AGRITEX.

Farmers reported that sometimes the water bailiffs misallocate water on Block 3. Since there are six water bailiffs, some bailiffs do not know the irrigation schedule when they come to work and may give water to the wrong plotholder.

Farmers reported a great deal of negotiation and flexibility regarding irrigation on Block 3. Farmers attempt to trade or exchange irrigation turns if one farmer cannot irrigate on his appointed day. For example, if one farmer is supposed to irrigate on Monday, but has a wedding he must attend, he will try to exchange irrigation days with his neighbor. If that is not possible, he might steal water the next day for his crops. If he is caught, he will have to pay a $10 fine to the IMC. In this situation, the IMC would discuss with the farmer why he should not delay his irrigation turn again.

In Blocks 1 and 2, the water bailiff monitors the pipelines and sometimes helps farmers move the pipes to their proper location. The pipelines are moved on a fixed rotation schedule, and there is little or no negotiation or flexibility in irrigation turns.

There was great variation in farmers' responses regarding the number of days between irrigations. Some farmers claimed 2 weeks between sprinkler irrigations, other claimed over a month.

Maintenance Fees. All plotholders must pay $145/ha/year to the IMC. The committee gives the money collected to the AGRITEX staff. It was reported that 98 percent of the farmers pay this fee, which is really a water charge. Those who refuse to pay for an extended time are evicted from the scheme. The IMC cooperates with AGRITEX if eviction is necessary.

Flood Versus Sprinkler Irrigation. Though farmer opinion was divided over which system -- flood or sprinkler -- was better, most felt that when the pipes were operating properly, the sprinkler system was best: a farmer could simply set it and leave. There is also no confusion over turns, as the pipelines are changed on a pre-determined schedule. Another farmer said he preferred the sprinkler system when it was working properly because he did not have to level his field. He felt that flood irrigation required level fields.

Other farmers did not like the overhead sprinkler system because they claimed that on windy days the water does not reach all areas of the plot. Others felt that the sprinkler heads were not high enough when maize was mature. When the maize was tall, the sprinklers could irrigate only a 2-m diameter, instead of an 18-m diameter.

Considering the current leaky pipes, most farmers preferred flood irrigation. Though there are problems with the flood irrigation system, most felt that it currently delivered a more adequate water supply than the sprinkler system, resulting in better crops.

Water Equity. Virtually every farmer contacted said that all farmers receive approximately equal amounts of water. This was true for both flood and sprinkler systems. They were not satisfied with the adequacy or reliability of the water, but felt that all plotholders were equally disadvantaged.

AGRITEX staff gave different information. They said that there is an inequitable distribution of water, particularly on the flood irrigation system. They claimed that farmers near the tail of the irrigation system sometimes receive no water at all.

Ownership and Identity with the Mutema Irrigation Scheme. All farmers contacted except one believed that Mutema "belonged" to AGRITEX, not to the farmers. As AGRITEX owns the land, this response is technically correct. The responses, however, do demonstrate the farmers' lack of identity with the scheme. Mutema is "theirs" (the Government's), it is not "ours" (the farmers'). Only one farmer expressed a sense of ownership at Mutema. He said that it was half AGRITEX's and half the farmers'. AGRITEX owned the land, but the plotholders did the farming.

Problems. Almost all farmers agreed that leakage in the pipelines and seepage in the canals were the worst problems at Mutema. Until these problems are solved, little could be done to improve the system. Yet, they are pleased with their winter/summer crop rotation, and they produced good yields before the system deteriorated. When there is sufficient water, more than one farmer stated, "farming gives us great pleasure."

Problems are compounded during drought. When water is plentiful, farmers felt that all their problems would be less severe. One farmer said that dry weather causes farmers to make "mischief" in the gravity irrigation system. The leaky sprinkler pipes force those farmers to "mischief" also.

On the gravity irrigation system, such mischief includes a great deal of water theft, particularly when the water bailiff is absent. Mutema farmers take water destined for other Mutema farmers, and dryland farmers adjacent to the scheme take Mutema water.

In the sprinkler irrigation system, farmers sometimes move the pipelines to unauthorized locations to give their plots an additional turn of water. Those farmers with plots next to the hydrants sometimes change the pipelines to their blocks. Farmers reported that when such violators are caught, the water bailiff forces them to stop, and they are fined.

Another farmer claimed that some plotholders are blamed for pipe problems they did not cause. For example, after a plotholder has set a pipeline and left, a rubber gasket may "blow," lowering pressure throughout the pipeline. A water bailiff may see this and accuse the plotholder of purposely damaging the pipe so that he could receive more water.

Problems also include misunderstandings and frustrations between plotholders and the water bailiffs. Two water bailiffs stated that during a drought, farmers blame the water bailiffs for the lack of water. The bailiffs said that the farmers act as if "we are gods" who can make the water magically appear. Under such stress, the bailiffs reported, farmers demand water every three days, a clearly impossible request.

Another farmer described a problem between the plotholders and AGRITEX. He claimed that farmers once asked the AGRITEX staff if a group of farmers could buy some new pipes on their own at no cost to AGRITEX. The staff replied that that was impossible as "private" pipes would affect the pressure and irrigation on the "public" pipes. Though the farmer admitted that the AGRITEX response was logical and reasonable, he claimed that it still caused resentment in some farmers.

This same farmer also speculated that farmers would not allow AGRITEX staff to concentrate on the plots and soils where the water would do the most good. He claimed that all Mutema plotholders demand water, despite potential inefficiencies in some parts of the scheme.

Another constant problem to the farmers is the maintenance fee. They do not understand why they should have to pay this fee when they are not receiving adequate and reliable water.

Conflict. During prolonged drought, conflict seems prevalent at Mutema Irrigation Scheme. Most conflict is related to water shortage. One farmer said "When it is hot and there is no rain, there is trouble."

Most disputes are between two farmers, or between farmers and AGRITEX staff. At times, many farmers reported, the disputes turn violent, with participants exchanging blows. One AGRITEX staff member said that farmers sometimes come to his office, ready to fight with the staff. The IMC chairman and vice-chairman stated that farmers often physically threaten them when a drought is imminent. Water bailiffs tell of "boiling" farmers, desperate to get water to their plots.

The conflicts, though sometimes violent, are usually short-lived. Although disputes can be common, each individual dispute does not last long. The IMC tries to calm the farmers.

4. System Maintenance

In general, scheme maintenance is the responsibility of the scheme's irrigation manager, but there are some specific responsibilities for various sections.

Pumps, boreholes and underground pipes are the responsibility of the Ministry of Water Development. The Ministry of Water Development checks and services the electric motors and the pumps and bearings two to three times each year. The pump attendants are employed by the Ministry of Water Development, but they work in conjunction with the irrigation managers. Broken underground pipes are repaired by the Ministry of Water Development only after the irrigation manager makes a report. The bill is paid by AGRITEX.

Electric installations and transformers are the responsibility of Zimbabwe Electricity Supply Authority (ZESA), which does regular maintenance and repairs damages. The cost is borne by the Ministry of Water Development and is then charged to AGRITEX. Mobile Electric Company is a private company, and is responsible for maintaining and repairing the electrical equipment between the transformer and the pumps.

Laterals and sub-main pipes are the responsibility of AGRITEX through the irrigation manager. The scheme has a workshop with an attendant who repairs pipes and sprinklers whenever possible. AGRITEX buys any new equipment.

Canals are also the responsibility of AGRITEX through the irrigation manager. Canals are cleaned daily (mainly sand abstraction) in summer by an AGRITEX employees. Should the need arise, plotholders help clean canals, especially after storms. Plotholders are responsible for the sections near their fields. If they don't clean their canals, water is withheld from them. In winter, canal cleaning is done only when needed. Repairs to the canal are done by AGRITEX with materials (i.e., cement) bought by AGRITEX.

E. CHARACTERISTICS AND PERFORMANCE OF THE AGRICULTURAL SYSTEM

The major summer crops are maize and cotton, with a small percentage of land in groundnuts. Winter crops are primarily tomatoes and sugar beans and occasionally wheat. Dryland cropping is not recommended in the area; however, some farmers do grow finger millet, sorghum, and some maize and vegetables under rainfed conditions.

The recommended crop rotation is maize or cotton followed by tomatoes or beans. Due to insect pests associated with vegetables, it is preferred that tomatoes be grown in alternate winter seasons with beans; i.e., maize-tomato-maize-beans. Farmers do not necessarily follow this rotation.

Suggested planting dates for summer crops are 1 October through 15 November; for winter crops, 1 May through 1 June (tomatoes and wheat) and 1 March through 15 April (sugar beans). Maize varieties R200, R201 and R215 are recommended for early maturity (short season). The cotton variety Albar G501 is preferred over the high-yielding variety Albar K602 because it is more drought resistant.

The major constraint to crop production is water availability and timing. Poor maintenance and high conveyance losses have lengthened the irrigation interval beyond what is required for adequate crop production.

Fertilizer use is minimal. Most farmers apply less than the recommended rate. In conjunction with water application problems, the observed effect is minimal. Most maize crops observed were nitrogen deficient, with possible deficiencies in zinc and iron. For example, the recommended fertilizer use of Compound D is 200 kg/ha at planting plus 50 kg/ha of ammonium nitrate at 6 weeks and 10 weeks. A farmer interviewed indicated that only 50 kg/ha of Compound D was applied before planting maize. No top dressing was applied.

Pests continue to affect yields. Animals such as mice, mongoose, goats, cattle, and baboons feed on seedlings, young plants, and seed heads. Birds are less of a problem. Red spider mites, red boll worms, and aphids are prevalent. Aphids and maize stalk borers have infested many maize fields. Though chemical controls are available, most farmers are unable to purchase them. According to an extension agent, however, about 60 percent of the tomato farmers use chemicals.

Weeds were observed overgrown and uncontrolled in about 40 percent of the fields. Most weed control is done manually by the farmer or by casual laborers.

Maize streak virus, common in most observed maize fields, can be controlled by controlling the vector with the chemical Rogor. However, most farmers have other economic priorities besides disease control.

In general, most inputs (fertilizers, seeds, chemicals) are available to the farmers, but are not used to their full advantage because of costs (personal priorities), crop management, or water availability at the field.

1. Production Inputs

The use of production inputs on the scheme is minimal. There are several factors which contribute to this: lack of income to acquire the inputs, lack of incentive to apply the recommended inputs due to water shortage (especially on the sprinkler system), and lack of credit.

Use of Improved Seed Varieties. Farmers on the scheme use improved varieties for cotton and tomatoes because they can acquire an income from these crops. Although they can acquire an income from sugar beans, the cost of seed is very high and farmers prefer to use seed retained from the previous season. Some farmers also use improved maize varieties, but since maize is grown for subsistence, most farmers use retained seeds.

Use of Fertilizer. Most farmers interviewed indicated that they use some fertilizer but the quantities applied are below the recommended rates for the scheme. Table 15 indicates the recommended fertilizer rates. These fertilizer recommendations are based on composite soil samples from each block. This sampling is conducted every three years by the agricultural extension officer. In addition to analysis for nutrients, soils are also tested for pests such as nematodes. From the crop budgets on pages 79-80, it is clear that farmers are applying fertilizer at rates below what has been recommended for the soil and a given crop.

The fertilizer rates applied by farmers are especially low for maize and tomatoes. Farmers' application rates for maize are between 100-200 kg/ha of Compound D and 200 kg/ha of ammonium nitrate; for tomatoes, about 200 kg/ha of Compound S is applied. Some farmers also use compounds that are not recommended for the crop (e.g., the use of Compound D for cotton).

Table 15. Recommended fertilizer use at Mutema.

Crop	Planting Time	Fertilizer Type*	Fert. Rate (kg/ha)
Maize	October	Compound D	300
		Ammonium nitrate	400
Cotton	October	Compound L	200
		Ammonium nitrate	200
Beans	April	Ammonium nitrate	100
Tomatoes	April	Compound S	1,000
		Ammonium nitrate	100

*N:P:K ratio for fertilizer Compound D (8:14:7), Compound L (5:18:10 + boron), and Compound S (7:21:7 + boron).

Pesticide Use. Use of pesticides is usually limited by lack of income to purchase them in recommended amounts, especially for cotton and tomatoes. This leads to heavy infestation of crops by pests and a reduction in yield. Pesticides are expensive and only farmers with a substantial income can afford to purchase them.

Extension Services. Farmers on this scheme are well served by their extension service. The extension worker to farmer ratio is about 1:80, which is well above the country's average ratio (1:800). Farmers are served by an extension worker in each block. Farmers also receive training from the extension workers who reside on the scheme.

Several methods are used to train farmers, including the training and visit method, master farmer training, field demonstrations, and individual problem solving. It is extremely difficult, however, to urge plotholders to follow recommended crop practices when farmers are too poor to do so. Additionally, some extension workers pointed out that it is difficult for them to urge farmers to invest in additional inputs when their crops are dying in the fields due to shortage of water.

Nevertheless, some agents said that they do give very general water application recommendations to the plotholders. These recommendations may not be very effective, they said, as there are only rough water measuring devices in the scheme.

They also stated that they usually have more problems working with wealthy farmers. These farmers, the agents claim, already know the recommended practices, but ask the extension agent to come to their plots anyway. The poorer farmers are reluctant to ask the extension agent to come to their plots because they believe that they will be a "nuisance" to the agent.

Credit Availability. The majority of farmers on the scheme are reluctant to deal with the Agricultural Finance Corporation because of problems associated with loans. Input packages have been delivered late and the farmers consider the interest rate charged by AFC as rather high. Therefore, farmers are reluctant to contact the credit agency, although it is readily available for use to acquire inputs.

Labor. Almost all farmers contacted said that the labor supply was sufficient. As Mutema plots are relatively small, existing household labor is usually sufficient. One farmer did point out, however, that if more water was available and he had very high yields, he would hire labor and pay them in kind. Another plotholder farming 1 ha said that he has two boys helping him. If he had very high yields, he would want to hire more labor, though he does not have the money to pay them.

A Mutema extension agent claimed that plotholders are sometimes wrongly accused of being "lazy" because some plotholders pick their cotton late. The extension agent explained that Mutema farmers prefer to pick ARDA estate cotton first, in exchange for cash which they can use while they wait for their checks from the CMB. The farmers claim that the CMB delays payment even when cotton is delivered early.

2. Yield

Yield estimates that the extension workers gave in their seasonal reports were quite high compared to what the farmers gave as the amount they realized. This discrepancy casts doubt on the yields quoted. Nevertheless, both perceptions are presented for maize, cotton, tomatoes, and beans in Tables 16 and 17.

3. Prices and Marketing

The marketing of summer crops is limited to cotton since most of the maize produced is retained for subsistence needs. Although some green maize may be sold to ARDA estate workers, farmers say that these sales are minimal. Cotton is sold to the Cotton Marketing Board at Birchenough Bridge. Most farmers receive prices below the A grade ($0.75/kg) due to pesticide stains.

Table 16. Extension seasonal report for 1984-85 and 1985-86 seasons at Mutema.

Crop	Area Planted (ha)	Maximum Yield/ha	Average Yield/ha	Standard Units	Total Prod.	Value/ Unit($)*
1984-85						
Maize	127.9	70 bags	40 bags	91 kg/bag	49160	16
Cotton	97.8	2500 kg	2000 kg	191 kg/bale	195600	.67
Beans	108.4	12 bags	10 bags	91 kg/bag	1080.4	75
Tomatoes	66.3	60 t	40 t	100 kg/t	2642	80
1985/86						
Maize	177.4	66 bags	35 bags	91 kg/bag	6209	18
Cotton	75.5	2700 kg	2600 kg	191 kg/bale	120800	.75
Beans	82	10 bags	8 bags	91 kg/bag	-	80
Tomatoes	108	70 t	40 t	100 kg/t	-	100

*In Zimbabwe dollars.

Table 17. Mutema farmers' production per hectare (1985-86).

Crop	Amount/ha	Standard Units
Maize	30 bags	91 kg/bag
Cotton	1500 kg	kg
Tomatoes	28 t	t
Beans	8 bags	91 kg/bag

Beans are marketed at the scheme. Private buyers purchase the beans and pay a farm gate price of about $80/bag (91 kg). Most of the beans are sold as dry beans. The farmers say they do not sell to the Grain Marketing Board because private buyers were giving them a price higher than the GMB price.

The marketing of tomatoes has created some controversy over the years. Most farmers expressed dissatisfaction and would consider other marketing channels if the problems associated with marketing to canning companies are not resolved. Farmers either sell to the canning companies, which provide seed to the farmers, or to private buyers.

Farmers reported that marketing through contracts with the canning companies has created problems because farmers are not given a statement of the amount deducted for transport and seeds. Some farmers are made to purchase seeds, and when they honor their contracts, seed costs are deducted again, meaning that farmers pay twice for the seed.

F. FINANCIAL AND ECONOMIC PERFORMANCE

Four factors have considerable impact on the economic and financial performance of the Mutema scheme:

1. The plot sizes tend to be small.
2. The performance of each block is significantly influenced by soil type.
3. Plotholders apparently have problems with marketing and with obtaining purchased inputs (such as seed and fertilizer) in adequate amounts in a timely manner.
4. Relatively low yields are associated with the apparent inability to deliver an adequate and reliable water supply.

Inadequate and unreliable water is generally a more serious problem on the "modern" portion of the scheme (blocks 2 and 3) because the sprinkler system is deteriorating. While the physical structures of the gravity-fed portion of the scheme (Block 3) appear to be badly deteriorated, farmers apparently have been able to adjust their methods of operating the system in ways which increase the adequacy and reliability of water supplies. Such adjustments are apparently not possible for those farmers who rely on the sprinkler system, particularly in Block 1 where sandy soils, which have limited waterholding capacity, are present. These differences in ability to adjust are reflected in the markedly different financial performances of farmers in the different blocks. Financial performance has a direct bearing on the ability of schemes like Mutema to contribute to the economic wellbeing of the country.

1. Mutema Crop Budgets

The representative crop budgets in Tables 18-21 were developed after interviewing farmers on the Mutema scheme who had plots ranging between .4 and 1.0 ha. There was relatively little evidence of intercropping with cotton and maize (summer season crops). During the winter season, slightly less than one-fourth of the land was left fallow. We were informed that farmers expected to receive an inadequate water supply and that was the principal reason that not all of the land was farmed during the winter season. Tomatoes, as a cash crop, and beans, largely for local use, were the two dominant crops grown during the winter season. The gross margins per hectare on Block 3 were 50 to 60 percent greater than the gross margins on Block 1 during the summer season. During the winter season, gross margins were 25 to 38 percent greater on Block 3 than on Block 1.

2. Gross Margins for the "Representative" Plotholders

The size of plot held by a farmer was primarily determined by the history of plot distribution, although some small plotholders found informal ways to expand the area they farmed. For example, one young farmer with surplus family labor planted his entire plot of 0.4 ha in cotton and reached an agreement with other plotholders, who for various reasons could not use all of their plots, to let the young farmer plant maize on the land that would otherwise be unused. The young farmer then agree to pay the water fees for the land he "rented."

Table 18. Crop budget for beans at Mutema (per hectare).*

	Block 1	Block 2	Block 3
Yield (t/ha)	0.9	1.0	1.4
Price ($/t)	880	880	880
Gross Income ($/ha)	792	880	1,232
		$	
Variable Costs			
Fertilizer			
Ammonium nitrate	81.20	101.50	121.80
Compound D	35.56	71.12	71.12
Labor for harvesting	148.35	154.45	196.52
Transport to farm	7.00	9.00	11.00
Ploughing	16.00	16.00	16.00
Total Variable Costs	288.11	352.07	416.44
Gross Margins	503.89	527.93	815.56

*In Zimbabwe dollars.

Table 19. Crop budget for tomatoes at Mutema (per hectare).*

	Block 1	Block 2	Block 3
Yield (t/ha)	24	30	35
Price ($/t)	100	100	100
Gross Income ($/ha)	2,400	3,000	3,500
		$	
Variable Costs			
Seed	25.00	25.00	25.00
Fertilizer			
Compound S	89.60	112.00	134.40
Ammonium nitrate	81.20	81.20	101.50
Pesticides			
Carbaryl 85 WP	38.08	38.08	38.08
Dimethoate 40 EC	22.00	22.00	22.00
Mancozeb 80 WP	61.90	61.90	61.90
Labor for harvesting	240.00	300.00	350.00
Transport to market	360.00	450.00	525.00
Transport to farm	8.00	9.00	12.00
Total Variable Costs	925.78	1,099.18	1,269.88
Gross Margins	1,474.22	1,900.82	2,230.12

*Zimbabwe dollars.

Table 20. Crop budget for cotton at Mutema (per hectare).*

	Block 1	Block 2	Block 3
Yield (t/ha)	1500	1800	2000
Price ($/t)	.66	.66	.66
Gross Income ($/ha)	990	1,188	1,320
	----------	$	----------
Variable Costs			
Seed (25 kg/ha)	6.00	6.00	6.00
Ploughing	16.00	16.00	16.00
Fertilizer			
Compound L	80.80	80.80	101.00
Ammonium nitrate	40.60	81.20	81.20
Pesticide			
Carbaryl 84 WP	76.15	76.15	76.15
Dimethoate 40 EC	22.00	22.00	22.00
Dimethane M45	10.20	10.20	10.20
Transport to farm	6.00	8.00	7.00
Transport to market	32.00	40.00	44.00
Labor for picking ($4/bale)	32.00	40.00	44.00
Labor for weeding ($30/ha)	30.00	30.00	30.00
Total Variable Costs	351.75	410.35	437.55
Gross Margins	638.25	777.65	882.45

*In Zimbabwe dollars.

Table 21. Crop budget for maize at Mutema (per hectare).*

	Block 1	Block 2	Block 3
Yield (t/ha)	2.70	3.00	3.50
Price ($/t)	180	180	180
Gross Income ($/ha)	486	540	630
	----------	$	----------
Variable Costs			
Ploughing	16.00	16.00	16.00
Fertilizer			
Compound D	71.12	71.12	88.90
Ammonium nitrate	40.60	40.60	81.20
Seed (25 kg/ha)	19.80	19.80	19.80
Transport to farm	6.00	7.00	9.00
Total Variable Costs	153.52	154.52	214.90
Gross Margin	332.48	385.48	415.10

*In Zimbabwe dollars.

More commonly, farmers with small plots or large families plant all of their land to maize and rely on winter tomatoes as their only cash crop. Producing enough maize to meet family subsistence needs on their own plot is a high priority objective of each farmer.

The number of tenants on the 237.2 ha of developed land on Mutema is listed as 347 (an implied average plot size of .68 ha) on the summary sheet of the GOZ report (1985). However, the official register on the scheme has a record of 291 plotholders (an implied average plot size of .82 ha). The distribution of plot size (GOZ, 1985) is 26 percent between 0.1 and 0.4 ha, 79 percent between 0.4 and 1.0 ha, and one plotholder with greater than 1.0 ha.

The average area farmed on the scheme during the 1984-85 and 1985-86 summer cropping seasons was 239.3 ha, or 101 percent of the area listed as developed. Cotton was farmed on 36 percent of the land and maize on 64 percent of the land during this period. During the winter season, only 77 percent of the area was farmed, with 40 percent of the area in beans and 37 percent of the area in tomatoes; 23 percent of the land was not farmed. We did not have information on plot size and cropping pattern by block, so it was assumed in the following analysis that the average plot size for all blocks was equal at .82 ha and the cropping pattern was the same for all blocks. In a more detailed study, these assumptions would need to be replaced with empirical information. For example, it is probably the case that the percentage of land not farmed during the winter season on Block 1 is considerably greater than the 23 percent average for the entire scheme.

The gross margins for the four principal crops grown by "representative" plotholders on each block in Mutema are presented in Table 22. The plotholders on Block 3 have a gross margin that is nearly 50 percent greater than plotholders who farmed the same amount of land on Block 1.

Table 22. Mutema cropping patterns and gross margins* by block (plot size of .82 ha).

	Summer		Winter		
	Cotton (.30 ha)	Maize (.52 ha)	Beans (.33 ha)	Tomatoes (.30 ha)	Total (.82 ha)
	$				
Block 1					
Gross margin/ha	638.25	332.48	503.89	1,474.22	
Gross margin/plot	191.48	172.89	166.28	442.27	972.91
Block 2					
Gross margin/ha	777.65	385.48	527.93	1,900.82	
Gross margin/plot	233.30	200.45	174.22	570.25	1,178.21
Block 3					
Gross margin/ha	882.45	415.10	815.56	2,230.12	
Gross margin/plot	264.74	215.85	269.13	669.04	1,418.76

*In Zimbabwe dollars.

In all cases, tomatoes were the most important cash crop, accounting for nearly half of the total gross margins. However, these figures do not reflect the high level of uncertainty for both price and grade associated with marketing tomatoes from the Mutema scheme. The two crops grown for family and local consumption (maize and beans) have lower gross margins than the cash crops. That Mutema farmers continue to grow maize and beans indicates that gross margins are not a good single indicator of the importance of a crop to a plotholder. However, if this limitation is kept in mind, gross margins can be useful in evaluating the effectiveness of an irrigation scheme.

3. Income Objectives, Payment Capacity, and Plot Size

ARDA has stated the objective of achieving an income level for settler families on ARDA schemes of twice the Universal Poverty Datum Line (UPDL) of $1,680/year. While Zimbabwe has a general goal of increasing rural incomes, no specific income objectives have been established for schemes like Mutema. However, much of the discussion about income objectives presented in the chapter covering the Tsovane scheme applies to schemes like Mutema, and that discussion is not repeated here.

In Mutema, there appeared to be conflict among the implied objectives of 1) getting as many plotholders as possible on a scheme, 2) creating a situation that would allow the plotholders to generate an adequate income from their plot, and 3) enabling the plotholders to have sufficient payment capacity so that they can pay the irrigation fees specified by the agency. The conditions on the Mutema scheme and the interrelationships among these objectives are presented in Figure 5.

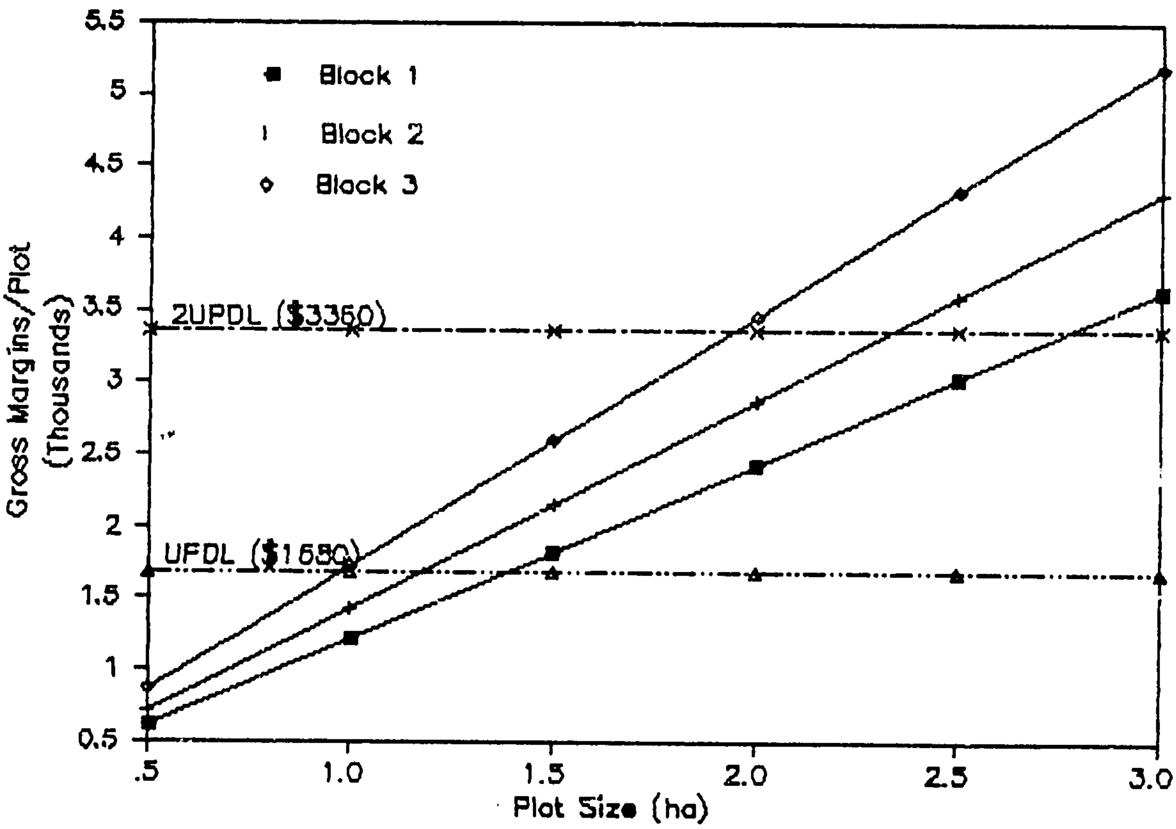


Figure 5. Plot size, income, and payment capacity on Mutema.

The gross margins for plotholders on the three blocks for different plot sizes are depicted by the three lines which slope upward and to the right in Figure 5. Gross margins would not reach the UPDL until farmers were cultivating 1.0-ha plots in Block 3 and nearly 1.5-ha plots in Block 1.

If the objective of plotholder income were set at the UPDL and all family income was generated from the plot, the payment capacity of a plotholder would be as indicated by the gross margin in excess of the UPDL line. For example, if a plotholder on Block 3 had 2.0 ha, gross margins would be slightly more than 2 UPDL and payment capacity would be slightly greater than $1,680 for the 2.0-ha plot. Payment capacity for a plotholder on Block 1 would be less than half of this amount.

Currently, only those plotholders on Block 3 cultivating a plot larger than 1.0 ha would have any payment capacity if the UPDL income objective was taken seriously. The required increase in gross margins for each .82-ha plot required to achieve an income objective equal to the UPDL for three payment levels are presented in Figure 6.

The first bar for each block in Figure 6 indicates the percent of current gross margins required to reach the UPDL income level if no payment for O&M or capital costs was imposed by the irrigation agency. The second bar for each block indicates the percent of current gross margins required to achieve the UPDL income level if a payment of $300/ha was imposed. The third bar indicates the percent of current gross margins that would be required to achieve the UPDL income level if a payment of $960/ha was imposed. A payment of $960/ha is based on an O&M charge of $400/ha each year plus a capital repayment charge of $461/ha each year. A capital repayment charge of $560/ha each year would permit the repayment of a $3,039/ha investment with a lifetime of 10 years (a normal life span for sprinkler equipment) and an interest rate of 13 percent.

4. The Economics of Rehabilitation

If inadequate and unreliable water delivery on Mutema are to be dealt with, both the gravity system on Block 3 and the sprinkler system on Blocks 1 and 2 need rehabilitation. To justify such rehabilitation, the question to answer would be "Would rehabilitation of the Mutema scheme effectively accomplish the objectives?" If the only objective was to improve income levels, it is clear that such a rehabilitation would be effective. If, however, dual objectives were made to 1) bring incomes up to a specified level (e.g., the UPDL level) and 2) collect payments from the plotholders to cover O&M costs and repay some of the capital costs, the answer is less clear. The JFW team was not able to address this question in the time available, but they were able to determine some operational procedures for dealing with the question if more time had been available. Those procedures are reported in this section.

It is clear that the issues of average plot size and distribution of plot sizes must be recognized. It is not that there is a single "best" plot size, but there is a strong relationship between plot size and the economic rent that can be generated from that plot. For any

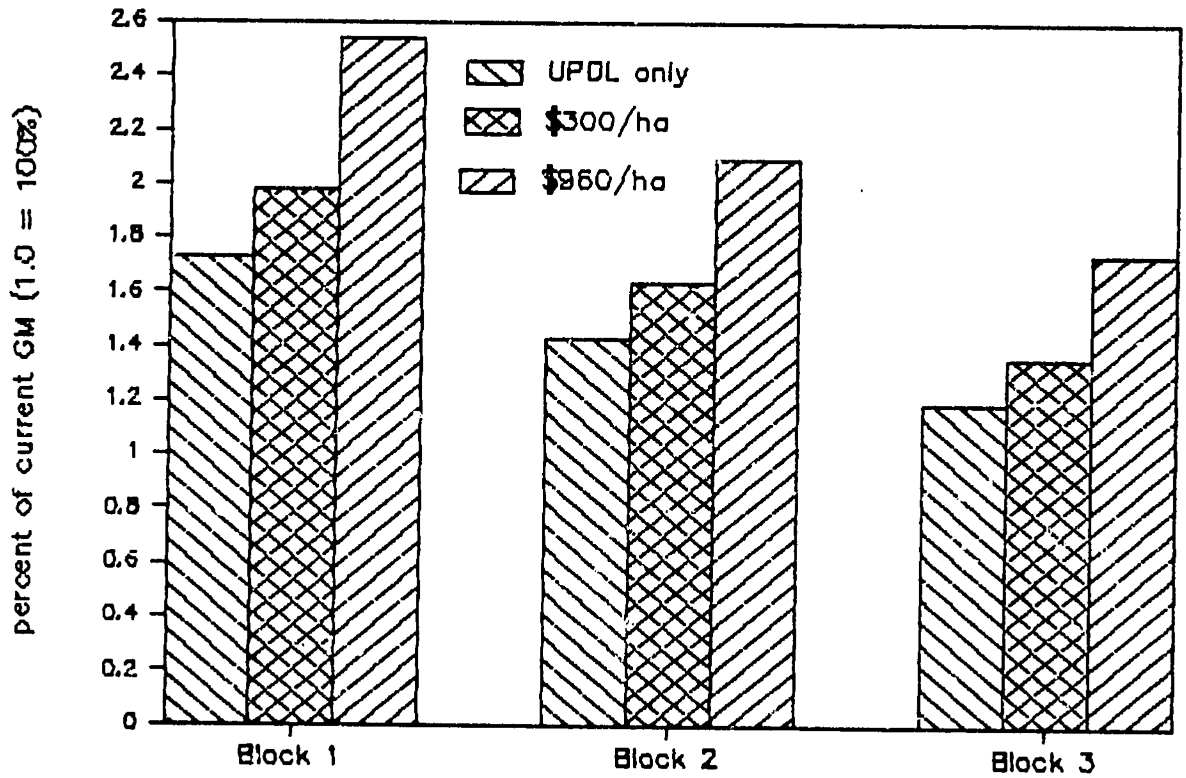


Figure 6. Percent increase in current gross margins required to meet UPDL and O&M payments (Mutema).

given level of economic rent, how the rent will be allocated between plotholder income and payment to the irrigation agency for O&M costs plus at least some capital costs must be determined. While this is a policy issue that must be dealt with by Zimbabwean policy makers, irrigation professionals can provide the policy makers with the most objective information available about the consequences of their choices.

One of the most difficult factual issues that needs to be addressed in Mutema is determining the likely O&M and capital costs for rehabilitating the sprinklers in Mutema. One way to make the first estimate of such costs would be to use cost records from similar schemes that have better financial records. ARDA operates a sprinkler system at Middle Save scheme, located a few miles away. While this ARDA scheme and Mutema are different, the O&M and capital costs from Middle Save could be used to estimate the expected costs of rehabilitating the Mutema sprinkler system. These costs could then be used to estimate the increase in gross margins that would be required if the rehabilitated Mutema system was to meet specified income and payment capacity objectives.

Once this information was known, agronomists, engineers, and farm management specialists could estimate if such an increase in gross margins was feasible. An interdisciplinary team of Zimbabwean irrigation professionals should be able to generate such information from a relatively short field study. The reasonableness of the results could be determined by discussing the results with selected farmers and other irrigation professionals who work in the immediate area.

Site conditions and gross margins indicate that Block 1 and Block 2 are significantly different from one another, even though both are served by sprinkler systems. Since Block 3 is served by a gravity irrigation system, the alternatives available for rehabilitating Block 3 are significantly different from blocks 1 and 2.

In evaluating the economics of rehabilitating Mutema, the three blocks should be treated as three incremental alternatives. It is possible, for example, that detailed analysis would show that it was economically justifiable to rehabilitate Blocks 3 and 2, but not Block 1. In such a case, the social problems associated with rehabilitating part of the scheme may be so great that partial rehabilitation may have to be rejected as a feasible alternative. Lumping the three blocks together in analysis may indicate that there is no economic justification for rehabilitating the entire scheme. The objective of increasing rural incomes in the area may be deemed so important that Block 1 would be rehabilitated even if O&M costs, but no capital costs, could be recovered. Such a decision would not be wrong, but it is important to fully understand the basis for the decision. The situation at Mutema, with three blocks that significantly differ from one another, illustrates the importance of treating parts of schemes that have significantly different characteristics as incremental alternatives within an analysis of the economic and financial feasibility of rehabilitation and irrigation development alternatives.

Developing sound results depends on tailoring studies to the specific scheme. However, once this type of information is accumulated from a series of such studies, it is usually possible to reach more general conclusions and to develop rough guidelines which are of greater value to policy makers.

5. Value of Water on Mutema

As stated above, the Mutema scheme is capable of generating income in excess of the income required to pay for the variable costs of production. That excess can be termed the economic rent. This rent can be allocated among the inputs that are regarded as "fixed" inputs, such as family labor and management and the resources represented by the Mutema scheme. In the long run, these "fixed" inputs would not be retained in the production process unless they received an adequate share of the economic rent. The problems associated with allocating economic rent are important, but the allocation discussed in this section is highly simplified, in that all of the economic rent is attributed to the irrigation water. The result is referred to as the "value of water."

It would be better to allocate an appropriate amount of the gross margins to family labor, irrigation agency payments, and so on, but that will not be done at this point. Because of the special assumptions used here, the term "value of water" has a very restricted meaning: it is the gross margin per 1,000 m^3 of gross diversion of irrigation water. The purpose of doing this exercise is to express the economic rent in terms of water rather than land or family labor. While the value of water calculated in this manner should be used cautiously, it does provide information that will allow policy makers to more carefully consider where water should be used and what the value is of using water more efficiently.

Table 23 presents the value of water for each of the three blocks for three situations. One represents the current situation. The gross diversion per hectare is less for Block 3 because irrigation efficiency is higher on Block 3. It is assumed that the gross diversion is the same for Blocks 1 and 2. This assumption may not be correct, and obtaining measurements for each cropping season (and ideally for each crop) is preferable for determining the gross diversion to each block.

Table 23. Value of water for irrigation at Mutema.*

	Block 1		Block 2		Block 3	
	Summer[a]	Winter[b]	Summer[a]	Winter[b]	Summer[a]	Winter[b]
SITUATION 1 -- Current[c]						
Gross margin ($/ha)	444	742	529	908	586	956
Delivered (1,000 m^3)	19.65	18	19.65	18	15.56	14
Required (1,000 m^3)	5.60	5	5.60	5	6.06	6
$/1,000 m^3	22.60	41	26.92	51	37.66	67
SITUATION 2 -- Efficiency + 25%[d]						
Gross margin ($/ha)	444	742	529	908	586	956
Delivered (1,000 m^3)	15.55	14	15.55	14	12.38	11
Required (1,000 m^3)	5.60	5	5.60	5	6.06	6
$/1,000 m^3	28.54	52	34.01	64	47.30	84
SITUATION 3 -- Yields + 20%[e]						
Gross margin ($/ha)	640	1,282	756	1,567	841	1,959
Delivered (1,000 m^3)	19.65	18	19.65	18	15.56	14
Required (1,000 m^3)	9.62	9	9.62	9	7.62	7
$/1,000 m^3)	32.57	71	38.47	87	54.05	138

*In Zimbabwe dollars.
[a]Cotton (37%), maize (63%).
[b]77% farmed. Gross margin based on .52 ha of beans and .48 ha of tomatoes.
[c]Irrigation efficiency is 29% on Blocks 1 and 2 and 39% on Block 3.
[d]Irrigation efficiency is 36% on Blocks 1 and 2 and 49% on Block 3.
[e]Irrigation efficiency is 49%.

The second situation considers a 25 percent increase in irrigation efficiency and the net application of the same amount of water as in the current situation, with no change in the gross margin per hectare. If water was short at Mutema, it is very likely that any increase in irrigation efficiency would result in an increase in the net application of water.

The third situation represents a situation where it is assumed that yields will increase 20 percent as the result of increasing irrigation efficiency to 49 percent, keeping gross diversions at current levels. In the third situation, it is also assumed that variable costs would not increase. Once again, it would be desirable to replace as many of these assumptions as possible with empirically derived information.

In situation 1, it can be seen that the value of water is higher during the winter cropping season than during the summer cropping season. During the winter cropping season, there is only enough water to farm 77 percent of the land. Situation 2 is straight forward in that the value of water is higher because the economic rent per hectare is allocated to about 20 percent less water. In Blocks 1 and 2, less water would have to be pumped, which would save pumping costs and the energy used to pump water.

Situation 3 is more involved, but reflects a situation more likely to occur as increased irrigation efficiency is used to increase the amount of water delivered to the plants in the field. An irrigation efficiency of 49 percent should be easily obtainable on schemes like Mutema, particularly on areas like Blocks 1 and 2. If this sort of analysis were used, it would be important to develop factual guidelines on the impact on crop yields of increasing the water delivered to the fields.

6. Conclusions

It probably makes more sense to talk about the "effectiveness" of a scheme such as Mutema rather than the "economic efficiency" of Mutema. Based on the information contained in the crop budgets and the gross margins per plot (Table 20), Mutema is probably not economically efficient, even if conservatively low values are placed on "fixed" resources such as family labor, O&M costs, and capital costs.

Yet Mutema as it is may not be a good indicator of what it could be. Mutema's water supply is inadequate and unreliable. In other situations in Zimbabwe, as well as in much of the rest of the world, farmers do not adopt a high-yield, irrigated farming system unless they have a reliable and adequate supply of irrigation water. (Other conditions such as adequate and timely inputs and good markets for the things they produce are also important.)

There are many ways to rehabilitate a scheme like Mutema that would not be economically efficient. What is not clear is whether there is at least one way, or perhaps several ways, to rehabilitate Mutema which would be economically efficient. For this to occur, both O&M and capital costs would have to be strictly controlled, and farmers would have to be able to increase yields considerably. The plot size would have to be large enough to let farmers achieve an adequate family income and be able to meet the necessary repayment schedules. To design such a rehabilitation plan, further field work by Zimbabwean irrigation professionals would be required. Difficult and perhaps politically objectionable questions would have to be asked and answered by policy makers. "Should all of the scheme be rehabilitated, or should part of the scheme be abandoned?" "How do the issues of family income and payment schedules interact, and what would be acceptable tradeoffs between these two objectives?"

While there may be questions about economic efficiency, Mutema is effective in terms of increasing rural incomes. During recent years, Mutema has generated about $300,000 of gross margins each year. If Mutema had not been there, little of this income would have existed. There is little doubt that a rehabilitated Mutema could generate between two and three times this level of income. Such an outcome would clearly be compatible with some of the stated development goals of Zimbabwe. The challenge is to find a way to make such contributions to the rural income objectives of Zimbabwe while at the same time satisfying the broader financial and economic objectives of the country.

G. SYSTEM STRENGTHS AND WEAKNESSES

1. Strengths

Extension Training. It appears that Mutema has a good extension training program for farmers. The ratio of extension workers to farmers (1:80) is better than the national ratio of 1:800.

Farmer Involvement. Farmers appear to be motivated and hard-working and to genuinely want to improve their standard of living.

Soil Suitability. The soils, excluding the deep sandy soils in Block 1, generally are suited for sustaining long-term irrigation.

Water Supply and Quality. There is adequate groundwater (of good quality) to supply the sprinkler-irrigated section. The pumps appear to be in good condition.

Effectiveness. Mutema, despite its severe shortcomings, has effectively increased rural incomes.

2. Weaknesses

Leaky Pipes and Equipment. Results in very low application efficiencies.

System Design. There is no proper layout of furrow, flood, or border irrigation. Slopes are variable and too steep (3 percent on loamy sands) for irrigation.

System Conveyance. Measurements taken in all blocks show excessively high conveyance losses:

* 1.5 percent/100 m on the lined section of the main supply canal.
* 4.7 percent/100 m on the unlined section.
* 30 percent on the sprinkler laterals (i.e., from each hydrant to the sprinkler lines).

Irrigation Scheduling. There appears to be no provision for scheduling irrigations to meet crop water requirements. For example, the sprinkler irrigation section was designed with an irrigation interval of 7 days; however, farmers get water about every 12 to 14 days.

Water Allocation. It appears that there is "water anarchy" when water is scarce. Farmers will take any water that is available, even if it means they will be fined. Middle Save gets priority in water allocation over Mutema in times of water shortage.

Equipment Procurement. The current practice of procuring equipment (in excess of $1000) through the tender board is a constraint. The procedure appears to take too long and the board is far removed from Mutema. As a result, Mutema farmers are losing the monies allocated to them by the Ministry.

Budgetary Control. The irrigation manager has no control over budgets. As a result, most sprinkler equipment breakdowns have gone unchecked for years.

System Vulnerability. The system is vulnerable to breakdown; particularly if critical components (such as bearings) break and cannot be found in the country. This seems likely to occur in the future (as has already happened to pump 2) since system maintenance appeared to be low to non-existent.

Production Inputs. The usage of pest controls, fertilizer, and water management is very low.

Potential Rural Income. Significant potential increases in rural income are not being realized due to the problems indicated above.

IV. MUTAMBARA IRRIGATION SCHEME

A. INTRODUCTION

The Mutambara irrigation scheme was one of the first pilot schemes in Manicaland Province. The scheme is in the Mutambara Communal Land in Chimanimani District. Mutambara is 75 km from Mutare, 65 km from Chimanimani, and 12 km from Cashel. The scheme is served by tarred roads. A plan of the scheme is shown in Figure 7.

The scheme is in agro-ecological region 3 at an altitude of 1100 m above sea level. It has an annual rainfall of approximately 785 mm and an estimated annual evaporation of 1790 mm.

The gazetted area of the scheme is 400 ha, but the developed area is about 145 ha. The Government of Zimbabwe reported approximately 152 ha under cultivation in 1984. Alluvial loamy sands cover 21 percent of the scheme. Seventy percent of the scheme area is sandy clay loams. The remaining 9 percent are shallow, gravelly sandy loams.

The water supply for the scheme comes from the Umvumvumvu and Ruwako rivers. The scheme is fed by a gravity-run, lined main canal from the Umvumvumvu River and is supplemented by the flow through a gravity canal from the Ruwako River. Mutambara is a surface irrigation scheme with an irrigation cycle of [illegible] to 14 days. The scheme is distinct from the other schemes currently under study for the following reasons.

1. Mutambara was started by local initiative with some influence from the local mission. In 1912 the local people dug a furrow from the Umvumvumvu River to secure food production to alleviate the effects of the drought experienced in 1912. It has since been expanded due to pressure on the drylands.

2. Mutambara has experienced government interference from the 1940s to 1974, when the resident irrigation manager left the scheme. The scheme was forcibly closed due to the farmers' refusal to pay increased water rates. Chief Mutambara was detained during this period.

3. After 1980 the scheme was reopened. It is currently operated by an elected management committee using donated equipment for maintenance and repair from the District Development Fund. The community is solely responsible for providing labor.

4. The government does not provide funds for maintenance and, therefore, does not incur operating costs. It is an interesting example of a self-managed scheme. Although the scheme has management and financial problems, it demonstrates possible long-term trends and the implications of devolving responsibilities to a community, which policy makers should note.

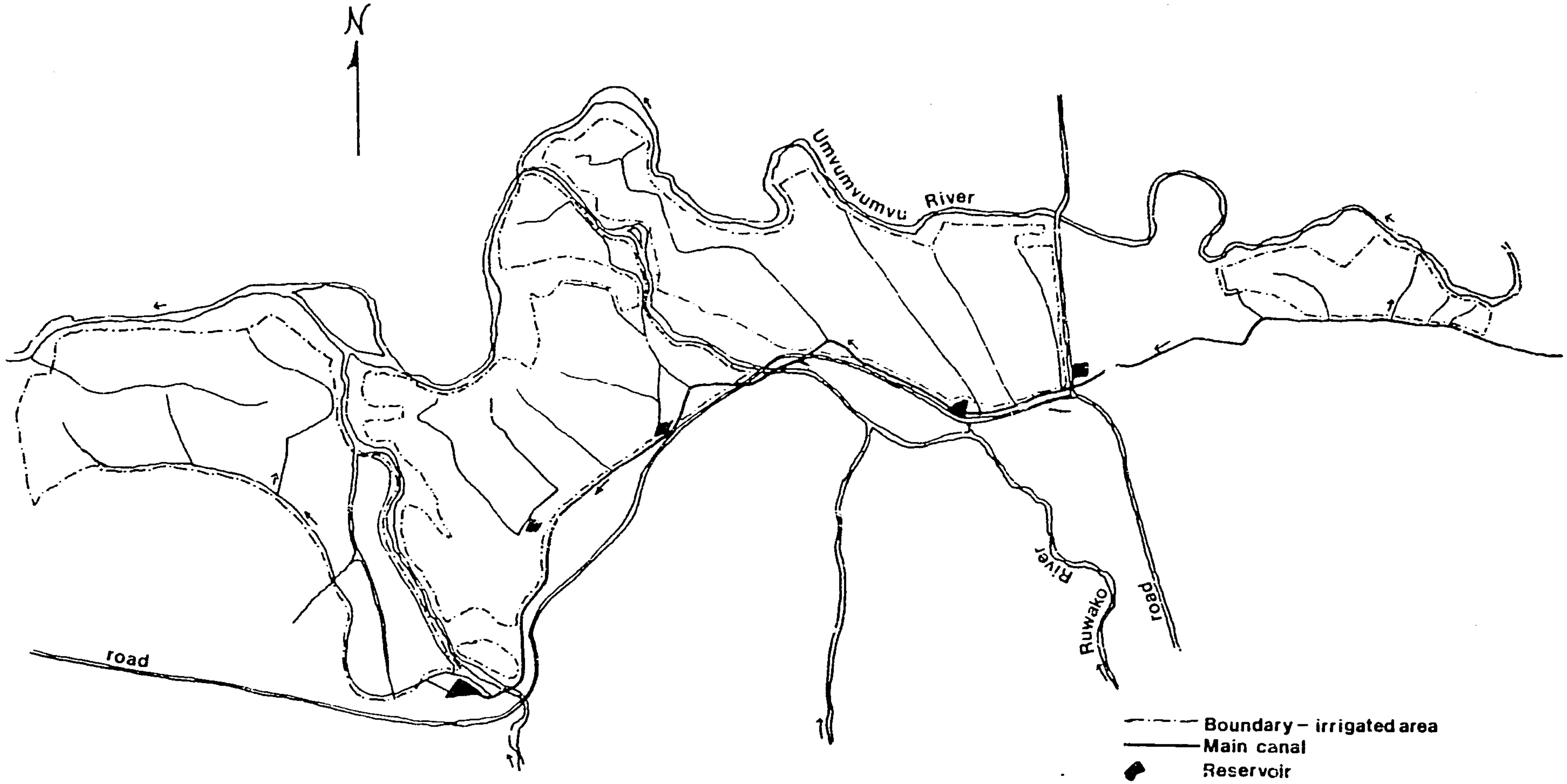


Figure 7. Mutambara scheme plan.

B. THE PHYSICAL SYSTEM

1. Hydrology

The main sources of water for the scheme are gravity releases from the Umvumvumvu and the Ruwako Rivers. The Ruwako has a catchment area of about 75 km^2 and has almost perennial flow. For example, at the end of the 3-year drought in 1984, the Ruwako still had a discharge of about 10 L/s. It is not metered so actual flow records are unavailable. The Umvumvumvu has a catchment area of about 200 km^2 at Mutambara, and the nearest measuring station is at the old Cashel Road Bridge, 433 km away.

Supply to the scheme is provided by diversion weirs on both rivers. On the Umvumvumvu, the weir is about 5 km from the field edge of Block A. The weir on the Ruwako River is about 100 m from the river's crossing under the road to Mutambara School.

The existing water right is about 151 L/s (GOZ, 1985). Peak water demand from November to January is estimated at 11,500 m^3 gross/day (GOZ, 1985). Given the current water right, a maximum delivery of 13,032 m^3 in 24 hours is allowed. Actual supplies and supply variation with time are not available since no records are kept. However, the variability in supply can be estimated using the flows in the Umvumvumvu River (MEWRD). The contribution of rainfall to crop water requirements is about 300 mm during the summer wet season. Little effective rainfall occurs during the winter dry season.

2. Soils

The irrigated area comprises two major groups of soils: those that have formed on terraces in alluvium from sandstone and mafic rock and those that have formed on gentle slopes in colluvium from basic rock, mainly dolerite. The soil survey performed by consultants (GOZ, 1985) covered 214 ha. However, only 179 ha are suitable for irrigation, and of this amount, 79 ha have severe limitations. Approximately 150 ha are currently irrigated.

The alluvial soils consist mostly of deep loamy sands with low available water capacity (about 6 percent), rapid infiltration (31 cm/h), and low fertility. Soil reaction is slightly acid (pH 6.1, CaCl), and the cation exchange capacity is less than 6 milli-equivalents/100 g of soil. These soils occupy about 40 ha at the tail of all blocks. They have been classified as Class S, restricted.

A small (5 ha) terrace in Block E consists of very fine sandy loam over silty clay loam, which becomes mottled with depth. These soils have high available water capacity (18 percent), moderate fertility, and good structure. They are highly suitable for irrigation.

The colluvial soils occupy about 134 ha of irrigable land. Most of this comprises moderately well-drained, red, sandy clay loams; some with sandy loam or loamy sand surface layers. These soils have moderately high available water capacity (13.5 percent), moderate infiltration, and low fertility. Soil reaction is generally neutral to mildly alkaline (pH 6.5 - 6.9). Base saturation is high, but the cation exchange capacity is low; hence, the ability to retain nutrients is low. Fertilizer applications, therefore, should be split over the growing season. These soils have been classified as either Class A or B, and are suitable for sustained, long-term irrigation. They occur as broad bands in Blocks A, B and F.

Similar, but shallower (less than 1 m deep) and very cobbly, soils occur primarily in Blocks C, D and E. Some have truncated (eroded) profiles, and most have an abundance of fine angular quartzite and cobbles. Soil structure is poor, and the available water capacity is low due to the presence of rocks. These soils have been classified as Class C, restricted suitability.

In summary, about 100 ha are suitable for irrigation without restrictions, 39 ha are restricted due to shallow depth to bedrock and stoniness, and 40 ha are considered too sandy to irrigate effectively. Field observations of crops generally reflect differences in soil types, but are not a strict indicator. Management by the farmer (i.e., inputs) is also a major factor influencing production.

3. The Physical System

The physical system is described in detail in the Mutambara Feasibility Study (GOZ, 1985). The main supply canal from the Umvumvumvu River is lined and is initially rectangular in sections of stone and cement. The remainder is concrete-lined and trapezoidal in cross-section. The canal is 5 km long between the weir and the highest point of the system (Block A). The main canal has been repaired recently and the lining is in generally good condition, but some seepage losses occur.

The main supply canal is lined for 4.7 km to the steel pipe siphon over the Ruwako River. The Ruwako River diversion canal is unlined, and although recently repaired (1986), seepage losses occur. The Ruwako River supply augments the main supply at the discharge end of the siphon. From this point, the remainder of the supply ca. l (1.5 km) is unlined. The distribution canals are unlined and have a total length of approximately 7.5 km. Seepage losses are high.

The turnouts from the supply canal to the distribution canals have facilities for gates, but the gates themselves are missing or inadequate. The distribution canals have masonry drop and turnout structures which are in generally good condition. However, water is diverted using stones and mud. Field ditches are unlined and have significant seepage losses. The distribution canals and field ditches are generally overgrown and in poor condition. Maintenance is inadequate.

Water is applied to fields using a form of controlled wild flooding. The method is labor intensive and inefficient in water use.

In many cases the water supply is inadequate due to seepage losses. In other observed cases, water is plentiful and runoff occurs. Field application efficiency is generally low and inequalities in water supply occur widely.

Two night storage dams exist on the system, but only one, in Block F, has significant storage capacity. The other night storage dam, located in Block B, has a considerably reduced capacity due to siltation. At the time of inspection, these dams were not in use for undetermined reasons. Since the diversions are permanently open, the excess water is currently diverted back to the river.

Drainage from the system for excess water and runoff from rainfall is provided by eight natural waterways. Due to the proximity of the Umvumvumvu River, drainage is adequate and waterlogging does not appear to be a problem, except in areas of high seepage losses from the supply canals. The system is operated by a water bailiff under the direction of the irrigation committee.

4. Resource Conservation

Salinity and sodicity are not problems on this scheme. Localized waterlogging as a result of canal seepage is not extensive, nor does it constitute loss of cropland. However, stony soils at the upper ends of Blocks C, D, E and F were observed to be eroded in areas, including rills and some truncation of the soil profile.

Water in the Umvumvumvu and Ruwako Rivers is of good quality for irrigation. The water observed during field visits was clear with low sediment loads. Due to the slope of land above the sandy river terraces, farmers have attempted to contour or terrace their land in an effort to maintain and control water. As observed in the field, this practice has been beneficial and generally successful.

C. SOCIAL/INSTITUTIONAL SYSTEM

1. Social Structure

In 1912, during a very bad drought, the local chief and dryland farmers decided that they had to build a crude canal to irrigate their crops. This canal was built entirely by the farmers with no outside assistance. The irrigation scheme and agriculture continued to develop over the years, matched by the enthusiasm of the local community for irrigation.

In 1974, irrigation at Mutambara was halted due to a water rights dispute with the government. After Zimbabwe's independence in 1980, the water use issue was clarified and irrigation resumed. The Mutambara farmers themselves cleaned and re-opened the main canal.

Understanding the spirit of self-help and self-reliance is critical to the understanding Mutambara. The Mutambara community has a long history of managing their scheme by themselves, and the farmers very much want to retain that independence. Farmers stressed that this local initiative sets Mutambara apart from other irrigation schemes, particularly those managed by the government. They claimed that despite differences between farmers, they all pull together in a crisis. The worst that could happen to Mutambara, they felt, was to have outside interference in their scheme.

The local chief and irrigation committee officers said that they needed advice from outside experts on how to improve their scheme, but they did not need outside management. They wanted to be taught how to acquire loans, for instance, so that they clearly understand what is required of them. The chief said that farmers would pay for lining the canals if someone could help them understand how to obtain a loan.

2. Land

Technically, all the land at Mutambara belongs to the state, but the local chief has control over the land. The chief himself stated that the land belongs to him.

Individual farmers have life-long leases on their plots, and their children inherit these plots. One farmer stated that many years ago, farmers were each given a 3-ha plot. These plots were subdivided as children took over the land. Currently, the largest single plot holder controls about 1.2 ha of land, although extended families could control as much as 2 ha of land. The smallest plot was reported to be approximately 0.2 ha.

3. Power

Size of land-holding is not related to an individual's power or influence at Mutambara. One farmer stated that a very good farmer on 0.5 ha will have more influence than a poor farmer on 2.0 ha.

The local chief wields the greatest amount of power at Mutambara. Though he is not directly involved in the day-to-day operation of the irrigation system, his advice is often sought. His word is, in essence, the law at Mutambara. Mutambara irrigation committee members would not speak with the JFW team until they talked with the chief first and received his approval.

4. Outside Employment

Irrigation committee members stated that almost all Mutambara farmers are engaged only in farming activities. Other farmers, however, said that many of the males in the scheme have left to find work elsewhere; i.e., road-building, factories, and so on. Our observations were that it was often difficult to find farmers working in fields, and many of those who were there were females. One committee stated that even though some Mutambara plotholders may work outside the system, this employment was not significant. He stated that the Mutambara farms have been within families for generations, and regardless of outside employment, all Mutambara people consider the land and farming extremely important.

Approximately one-third of the farmers contacted were females. One stated that her husband was working in a factory in Harare. Females said that they face no sexual discrimination in regard to irrigation. One stated that with irrigation there are no seasonal employment changes, and she feels "fully employed."

5. The Irrigation Committee and Local Organizations

There is an irrigation committee at Mutambara that is supposed to manage the scheme for the farmers. There are 12 members on the committee, including a chairman and vice chairman. Each of the six blocks on the scheme are represented by two members who are elected yearly. The committee also hires a water bailiff, who helps distribute water throughout the scheme and helps in day-to-day operations. The chairman of the committee does not appear to have extraordinary powers or influence. He presides at committee meetings and helps with administrative details.

One of the most important functions of the committee is to collect a maintenance fee of $7.50/ha each year from each plotholder. These fees help pay the water bailiff and allow the committee to make minor capital improvements in the system. Despite the low rate, committee members stated that it is sometimes difficult to collect the fee from all plotholders, particularly those on Blocks E and F, the tail of the scheme. Some farmers on these blocks claim that they do not receive adequate water so they should not pay. Committee members said that all plotholders ultimately pay, although some of the farmers must be threatened with water cut-off before they will pay.

The committee tries to allocate water equitably, but sometimes farmers break water allocation rules. The committee, therefore, imposes a $14 fine for people stealing water during the day, and a $20 fine for those stealing water at night. One committee member said that the night stealing charge was higher because people sometimes steal water from the night storage dam in the dark. If a farmer steals from the dam, they reason, the violator is not just stealing from one other farmer, but from the entire irrigation community. Therefore, he should be punished more harshly. We were told that much water theft at night takes place when the moon is nearly full as farmers can see better. It was reported that such a $20 fine was levied and collected just one week before the JFW team's arrival.

One farmer stated that many plotholders willingly pay a $20 fine if it means that the water will save his crop. If a plotholder has spent hundreds of dollars farming a piece of land and he is desperately short of water, a $20 fine is considered a small price to pay for his livelihood.

Irrigation committee meetings are open, free-wheeling forums where everyone is welcome to speak. There are often open disagreements between farmers at these meetings, and there is no monopoly of opinions. Many of the Mutambara farmers contacted praised the committee because it did allow such freedom of speech and "good arguments." These farmers felt that a free exchange of ideas was healthy for the scheme.

One key informant, however, said that there is a fine line between diversity of opinion and simple disorganization. This informant felt that at the Mutambara irrigation committee meetings, unrestricted discussions were a result of confusion and conflict, not consensus.

There was a diversity of opinion regarding the committee's effectiveness. The committee called itself a strong, effective organization that tries to allocate water equitably throughout the system, even in a drought. For all its problems, the committee members felt that Mutambara was the best irrigation scheme in the area. Some farmers agreed with this assessment. They said that in times of water shortage, the committee does allocate available water effectively.

Other farmers, however, were more critical. One farmer stated that the committee members do not really care about the scheme and that the committee is not an effective organization. Another claimed that only relatives of the committee members receive sufficient water.

There are "farmers' clubs" at Mutambara that deal with special interests of farmers. These clubs can play an important role in Mutambara. There is, for instance, a group of Mutambara farmers in each block who are particularly interested in producing tomatoes. These clubs help farmers to obtain inputs and market their tomatoes.

One morning, the JFW team witnessed an open meeting of the tomato growers from Blocks D, E, and F. The purpose of the meeting was to compile a list of tomato growers for the coming winter season and plan for a "harvest feast" celebrating last year's crop to be held in a week's time. Approximately 35 people attended, about two-thirds of them female. The males and females were seated separately, but there was a great deal of discussion and laughter among all the farmers. One male led the discussion and urged people to volunteer money, food, drinks, or labor for the coming feast. Other male farmers carefully noted each voluntary contribution.

D. CHARACTERISTICS AND PERFORMANCE OF SYSTEM MANAGEMENT

1. Water Allocation, Distribution, and Application

The water supply to the scheme is covered in detail in the Government of Zimbabwe report (1985).

The estimated abstractions at the canal intake on the Umvumvumvu and Ruwako rivers were 130.5 L/s and 18.2 L/s, respectively. This indicates that the scheme is operating at or slightly below its water right requirement. However, only about one-third of the flow from the Ruwako River was being utilized.

There are considerable losses in the main and distribution canals. The losses in the lined section of the main canal were estimated at 40 percent. This results in a conveyance efficiency of 60 percent (GOZ, 82 percent). Distribution losses in unlined canals were estimated at 47 percent resulting in distribution efficiency of 53 percent (GOZ, 75 percent). This is due to seepage losses and breaks in the lined main canal, and to poor maintenance and overgrown weeds in the unlined distributaries. The Ruwako canal losses up to the siphon outlet were low: 3.0 percent/100 m.

The water is allocated by block every day. The flow to each block is allocated according to the size and number of farms in a block. There appeared to be an inequitable allocation between head and tail ends of the scheme. This could not be substantiated during this study given the time constraint.

Allocation within the blocks was also inequitable for different reasons: physical system constraints, nature of the soils, high seepage losses in unlined field canals, late plantings, and uncertainty of water supply allocated to each farmer. However, we were assured that the water bailiff and the committee attempt to allocate water equitably and to resolve water conflicts. There may not be equitable and adequate allocations, however, as some farmers reported a cycle of up to three months. The effect on the crop could be alleviated by rainfall. The reported total rainfall in this area is 300 mm (GOZ, 1985).

The method of irrigation is described in detail in the GOZ report. It was observed that due to late land preparation, proper land levelling and furrow preparation were not done. Wild flooding coupled with controlled ponding was observed. In some instances surface runoff was evident. One day was allocated to a farmer for irrigation irrespective of the size of his plot. This method of irrigation is labor intensive and very inefficient.

Application efficiencies could not be determined because water allocation was chaotic, flows were unreliable, and the method of irrigation was a matter of trial and error. However, it can be suggested that the overall project efficiency is low -- although efficiency was not fully analyzed in this study.

2. Water Adequacy, Reliability, and Equity

Adequacy. The scheme extracts more water than it is allowed in average years since it takes water from the Ruwako River without any rights. Even so, a combination of coarse soils, an inequitable allocation system, and large system losses lead to water inadequacy even in normal years (GOZ, 1985).

An informal interview with the irrigation committee indicated that inadequate supply was a major problem in the scheme. In drought periods, cultivated areas are reduced to about 0.04 ha for each farmer, with stringent policing by the committee. The two night storage dams ameliorate this problem to some extent. Inadequacy of supply increases from the head of the main canal to the tail, and from the head of the distributaries to the tail of distributaries. This inadequacy leads to conflict and water theft.

Reliability. Reliability is a problem since the water allocation schedule does not appear to be strictly enforced. One farmer in Block E said that he had not received water since planting in November (reported in February). Charges of favoritism by the water bailiff were also encountered. Again, reliability of supplies at the plot level appeared to decrease from head to tail in most canals (including the main canal).

Equity. Water flow to blocks ranged from one day to one week. The length of time is generally guided by the size of the block in qualitative terms. By the estimates of the irrigation committee, the smallest block had 11 farmers and the largest had 20 farmers with variable plot sizes.

Within blocks, it appeared that the tail farmers suffered most and they naturally had the most complaints. Farmers in Blocks E and F are estimated to have yields of 38-50 bags of maize/ha as compared to a normal yield of 75-80 bags/ha. This might not be due only to inequity in water supplies, but also to other factors such as sandy soils and poor crop management.

On the average, farmers at the head section receive water about once in 14 days, and those at the tail receive water, at best, once a month. The norms for irrigation are a 14-day cycle for maize and a 7-day cycle for tomatoes. Based on soil textures, the recommended cycles are 5 days for sandy soils and 9 days for the red sandy clay loam soils.

Recommendations to improve the adequacy, reliability and equity issues include the following:

* Decrease conveyance and distribution losses by rehabilitating the physical system

* Better organize water delivery and irrigation schedules, taking into account the soil type and crops (i.e., intra-block scheduling)

* Increase the capacity of night storage on the scheme.

3. System Management

Farmer Involvement in Irrigation Activities. All farmers contacted complained that the scheme did not have sufficient water during drought. If there are adequate rains, however, problems are relatively minor. One female farmer stated that in a drought, all farmers still receive water, but in smaller quantities. Another female farmer said that the lack of water is due to a lack of good water storage facilities, such as more night storage dams.

Other farmers said that adequacy and reliability were a function of the season. These farmers said they never know when they will receive irrigation water when there is no rain and the river is low. The JFW team encountered two farmers at the head of the system who were irrigating their maize in mid-February. Both farmers claimed that they planted the maize in December and that this was the first time they could irrigate -- two months after planting.

Farmers gave different answers about the equity of water distribution at Mutambara. In general, head farmers said that all farmers receive their fair share of water. They said that, at least, the water bailiff is supposed to distribute water equitably.

Tail farmers generally felt that head farmers receive more than their fair share of water. Some tail farmers stated that the night storage dams at the head give the head farmers greater access to water. Another farmer stated that when he needs water and cannot get it, he walks to the head and often finds that a farmer has finished irrigating and is allowing water to flow freely off his field, to waste.

Other farmers complained that favoritism is shown to committee members' relatives and friends. One tail farmer said that he is like a dryland farmer, since he receives water so infrequently. He claimed that in the past there was enough water to not only irrigate tail plots, but to also allow excess irrigation water to flow back into the river so that an irrigation system downstream could use it.

The JFW team did notice both irrigated and non-irrigated fields at the tail. Some of the crops at the tail did not appear to be receiving adequate water, but other tail plots looked very healthy, compared to the rest of the scheme. Water was flowing in some of the smaller canals at the tail. One female plotholder at the tail was irrigating, but wasting a great deal of water as it flowed off her field onto a foot trail. Additionally, some small canals at the tail were well-maintained, which usually indicates that water is being received. These observations tend to confirm that at least some tail farmers are receiving water, but that others are disadvantaged. Poor water management practices may be a primary contributory factor.

Farmers, therefore, are heavily involved in irrigation activities, either in operations or maintenance, or individually or collectively through the irrigation committee. This chaotic involvement, however, may sometimes contribute to poor system performance.

Many farmers recognize that there are problems at Mutambara. Plotholders claimed that lack of rain, misallocation of water, and clogged canals were all major problems.

The chief recommended that the scheme emphasize equitable access to water, saving water, and improving water use. The irrigation committee had more specific suggestions: the main canal should be fully lined, silt in the night storage dam removed, more night storage dams constructed, and a strong fence to keep out livestock should be placed around the scheme. One disgruntled farmer even suggested that more irrigation decisionmaking should be given to the AGRITEX extension worker. Mutambara farmers are thinking about how their system could be improved.

Conflict. With the perceived misallocation of water at Mutambara, there is bound to be conflict. Some farmers stated that they often become angry at other farmers and committee members and loud yelling ensues. One farmer at the head of the scheme claimed that last year two Mutambara farmers became so angry at one another over water that they began fighting with shovels. The committee was finally called in, and they had to summon the police from the nearby town of Cashel. The case was eventually referred to court.

The water bailiff is also supposed to help solve disputes. Though water conflicts appear to be relatively frequent at Mutambara, they do not appear to significantly affect system performance, as is the case in some other irrigation schemes.

Maintenance. System maintenance is the responsibility of the irrigation committee; i.e., they enforce the maintenance programs. The actual sand removal and weed cutting in the canals is done by the farmers. Farmers pay $14.50/ha/year in maintenance fees, including the water bailiff's pay. This money is kept by the treasurer, and is generally used to buy materials; e.g., cement required to fix broken canals and to pay the builders. Canal maintenance is done about twice a year, before and after the rains. People who fail to pay their maintenance fees are evicted from the scheme or denied water.

For main canal maintenance (cleaning) each plotholder sends one member to work. Those failing to do so pay $1.50 or are given larger portions to work on their own. The distributary canals are cleared by the plotholders close to them in the blocks.

At the moment, the main canals from Umvumvumvu and Ruwako diversions show signs of not being properly maintained. The main canal from Umvumvumvu has sand in it, and at several points the concrete is broken and there are visible signs of leakage. On the Ruwako canal, some sections are not lined and there are visible losses. The field canals are overgrown with weeds.

E. CHARACTERISTICS AND PERFORMANCE OF THE AGRICULTURAL SYSTEM

The historical cropping pattern has been maize in the summer followed by wheat. However, more farmers are planting tomatoes in the winter to take advantage of more lucrative canned tomato contracts. Normally it is not recommended that tomatoes be grown on the same land in successive years due to persistent pest and disease problems. Nevertheless, it appears that farmers who enjoy the profits from last year's tomato crop plan to grow tomatoes this year.

Minor amounts of cotton and groundnuts are also grown in the summer, though yields and income are unsatisfactory. Sugar beans and vegetables are other common winter crops. Historically, the cropping intensity has been about 185 percent. Large plots of dryland maize are prevalent adjacent to irrigated lands. Small vegetable gardens were also observed near dwellings.

Most farmers plant short-season maize, such as varieties R200, R201, R215 and ZS225. Both canning and fresh market tomato varieties are produced. Most farmers who grow wheat use seed from their previous harvest. This seed, Devule variety, has been an erratic producer, subject to lodging and leaf and stem rust (GOZ, 1985).

Fertilizer use is typically low; most farmers apply less than 50 percent of the recommended rate. Some farmers only apply fertilizer at planting and bypass top-dressings later in the season. Use of fertilizer is proportional to economics and water availability. Farmer interviews indicate that nearly all farmers use fertilizers to some extent and that about 20 percent use manure. Observations indicated nitrogen and phosphorous deficiencies in over half the fields visited.

Most fields observed had weed problems. Weed control is done manually, either by the farmer or by casual laborers.

Insect pests pose a serious threat to crop production, particularly tomatoes. Red spider mites, aphids and nematodes are chronic problems. Stalk borers and aphids are among the most pervasive pests for maize. Chemical controls recommended by AGRITEX are available, though informal interviews indicate moderate use by farmers.

Maize streak virus, transmitted by leaf hoppers, is a common disease for maize. Leaf blight was reported as the prevalent disease for tomato. Again, chemical controls are available, but it is uncertain how many farmers use these chemicals. Farmers have found moderate results using Mancozeb. Stem and leaf rust and maize streak virus have resulted in lower yields for wheat.

In summary, most farmers believe water availability is the most limiting factor to crop production. The uncertainty of receiving water affects planting date, fertilizer use, and ultimately, yields. Farmers also commented that if water was not limiting, tomato leaf blight would be the major concern.

1. Production Inputs

The use of inputs (from the farmers' perception) is limited by capital. Due to moisture stress on the land, farmers have been found to be unwilling to invest in inputs. Farmers would rather apply less than what would be recommended for the soil fertility status and prevalent diseases.

The Use of Improved Seed Varieties. Maize farmers on the scheme use R201 seed variety, but most farmers say that they retain some seed maize from the previous crop. Generally farmers in Blocks E and F have voiced the use of retained seed.

For sugar beans, most of the seed is retained due to the high price of seed. The cotton variety used by most farmers is Albar K602, which they purchase from the CMB in Mutare. For tomatoes, seed is provided on credit by the Cerebos company in Mutare. The pea seed variety, Greenfeast, is grown by the farmers. They get the seeds on credit from a canning factory in Mutare. The above are the crops considered because they contribute a substantial amount to the farmers' income.

Use of fertilizer. Fertilizer use is limited by lack of income from maize. Farmers argue that the price of maize does not justify the use of additional inputs. The rationale of this has not been looked into seriously. The amounts of fertilizer that are used are supplemented w :h manure by most farmers.

The fertilizer inputs given by farmers were not the same as those presented in the Government of Zimbabwe report (1985). It should be stressed that the use of fertilizer depends on moisture availability. Farmers in Blocks A and B are using more fertilizer (about 200 kg/ha of Compound D for maize) than reported in the GOZ report (150 kg/ha of Compound D). Farmers in Blocks E and F were found to apply less, with some farmers using only a basal manure dressing. Manure is used extensively by most plotholders on the scheme due to its low cost, but depending on its availability.

Aside from maize, cotton and peas are the main crops that are fertilized. Compound L is used mainly for peas and cotton, and a top-dressing of roughly 150 kg/ha ammonium nitrate is used in most areas.

Pesticides. Pesticides are mainly used on cotton and tomatoes. The major pesticides used are Carbaryl (sevin), Rogor (dimethoate) and Endosulfan 50 percent Wp (thiodan). The farmers gave the impression that application depends on availability and also the extent of infestation. Since most farmers have been growing the crops for several seasons, they have been given some training on pesticide use by a part-time extension worker.

Extension services. In this scheme the extension agent-to-farmer ratio is very high. One extension worker is available for the whole scheme and some farmers reported that they have never seen the agent on their lands since he came. This shows farmers are functioning without any advice from the extension services.

Credit Availability. Credit is limited since the farmers are not assured of a good crop. Although farmers may be willing to obtain credit, they are not anxious to deal with the Agricultural Finance Corporation, and most farmers say that the obligations of AFC are difficult to meet. Some farmers, however, get input packages from AFC.

2. Yield

Yield Per Crop. The yields of the scheme vary depending on the type of soil that the crops are planted in. There are three types of soil which probably will restrict plant growth due to low inherent fertility -- namely sandy soils, stony and shallow soils, and class A and B sandy loams. Crop yields also are bound to be lower due to incidence of leaf blight in tomatoes, lower than recommended fertilizer use, leaching of fertilizer in sandy soils, and the uncertainty of water, lack of water, low irrigation efficiency, and late planting dates.

The yield ranges in Table 24 were given during interviews with farmers on different blocks. Though yield varies depending on the block, only crop yield ranges are given here.

Table 24. Yield ranges for crops on Mutambara.

Crop	Yield Range (t/ha)	
Maize	2	4.5
Cotton	800*	1500*
Tomatoes	10	20
Peas	0.8	1.6
Sugar beans	0.5	1.5

*kg/ha

Yield Per Year. The yield for each crop in each year was not calculated due to lack of data on the actual area planted to each crop on the scheme.

3. Prices and Markets

Prices of agricultural commodities are divided into two categories: controlled commodity prices and free market prices for uncontrolled products.

Farmers at Mutambara grow maize and cotton, which are controlled commodities, and therefore receive the price determined by the marketing boards. Tomatoes and canning peas are commodities which farmers grow under contract with canning factories. The prices of these commodities are determined by the canning company. The farmers have no influence on the price. The price of sugar beans is determined by private buyers. Sugar beans and tomatoes are also sold to two secondary boarding schools near the scheme. Beans are sold for $85-$90/bag (91 kg).

The scheme is now near a GMB depot, which is about 20 km from the scheme. In previous years, the farmers sold grain in Mutare, leading to high transportation costs.

F. FINANCIAL AND ECONOMIC PERFORMANCE

The Mutambara scheme has low yields relative to the other three schemes examined by the JFW, but it is also a low cost scheme in terms of O&M and capital costs. Mutambara scheme is community-operated; no central organization exists to collect detailed information or to enforce or encourage specific farming practices or crop rotations. Cropping practices and rotations appear to vary more than on the other schemes, and our field survey was not intense enough to permit the analysis of all the situations found within the Mutambara scheme. Yields appeared to vary considerably from one major soil type to another, but poor management also resulted in low yields on some plots located on good soils. Because of the location of the scheme, some families probably have considerable non-farm income, but we gathered little empirical information on this issue.

Approximately 150 ha are irrigated at Mutambara, of which about 110 ha are fairly well suited for irrigation and about 40 ha are, at best, marginally suited for irrigation. As stated earlier in this report, the crop condition generally reflects the soil type, but soil type is not a strict indicator since farmer management (including effectiveness of irrigation) is also a major factor in crop condition).

The plot sizes vary from .2 ha to 1.2 ha, the largest plot on Mutambara. Because cropping patterns and practices vary from plot to plot, it is difficult to construct representative crop budgets for Mutambara. The crop budgets in the next section have been constructed based on 1 ha for the two principal soil conditions found on Mutambara -- restricted soil and suitable soil -- even though factors other than soil type contribute to the bimodal performance found on Mutambara.

1. Mutambara Crop Budgets

The crop budgets used in the Government of Zimbabwe report assumed optimum use of inputs, adequate water, and no soil limitations -- assumptions which led to higher yields than we found from either interviewing farmers or from observing crops in the field. The economic and financial performance of Mutambara is such that about two-thirds of the area has modest yields and gross margins (on suitable soils) and about one-third of the area has poor yields and low gross margins (on restricted soils).

Two crop budgets are presented below (Tables 25-29) for each of the five principal crops grown at Mutambara: maize, cotton, tomatoes, peas, and sugar beans. To give some perspective to the yields, note that cotton yields at Mutambara on suitable soil are one-half the yields at Tsovane and the cotton yields on restricted soil are one-fourth the Tsovane yields.

2. Plot Size, Farmer Income, and Payment Capacity

The crop budgets in the section above were used to develop the estimates of gross margins per plot, which are presented in Figures 8-11. To develop these estimates, the crop rotations in Table 30 were used.

Table 25. Budget per hectare of maize on Mutambara.*

	Suitable Soil		Restricted Soil	
	Quantity	Cost ($)	Quantity	Cost ($)
Yield (t/ha)	4		2	
Price/t ($)	180		180	
Gross Income ($)	720		360	
Seed	25 kg/ha	19.20	25 kg/ha	19.20
Fertilizer				
Compound D	200 kg	74.28	100 kg	37.34
Ammonium nitrate	150 kg	63.95	100 kg	42.63
Dipterex 2.5	2 kg	1.40	2 kg	1.40
Transport to farm	$1.00/50 kg bag	7.00	$1.00/50 kg	4.00
Packing material	44 bags	88.00	22 bags	44.00
Transport to market	$1.20/bag	52.80	$1.20/bag	24.60
Total Variable Costs		287.83		174.97
Gross Margin		432.17		185.03

*In Zimbabwe dollars.

Table 26. Budget per hectare of cotton at Mutambara.*

	Suitable Soil		Restricted Soil	
	Quantity	Cost ($)	Quantity	Cost ($)
Yield (t/ha)	1500		800	
Price/t ($)	.75		.75	
Gross Income ($)	1125		675	
Seed	25 kg/ha	6.00	25 kg/ha	6.00
Fertilizer				
Compound L	200 kg/ha	84.84	100 kg/ha	42.42
Ammonium nitrate	100 kg/ha	42.63	100 kg/ha	42.63
Transport to farm	$1.00/bag (50 kg)	6.00	$1.00/bag	4.00
Pesticides				
Carbaryl 85WP	2 kg/ha x 4 app	121.84	2 kg/ha x 4 app	121.84
Dimethoate 40 EC	1 L/ha x 4 app	44.00	0.5 L/ha x 4 app	22.00
Endosulfane 35 MO 2	2 L/ha x 4 app	19.54	1.2 L/ha x 4 app	11.72
Transport to markets	$5.20/bale	41.60	$5.20/bale	23.10
Packing materials	$2.00/bale	16.00	$2.00/bale	9.00
Total Variable Costs		382.45		282.71
Gross Margin		742.55		392.29

*In Zimbabwe dollars.

Table 27. Budget per hectare of tomatoes at Mutambara.*

	Suitable Soil		Restricted Soil	
	Quantity	Cost ($)	Quantity	Cost ($)
Yield (t/ha)	20		10	
Price/t ($)	100		100	
Gross Income ($)	2000		1000	
Seed	0.5 kg/ha	37.50	0.5 kg/ha	37.50
Fertilizer**				
Compound L	100 kg	42.42		
Ammonium nitrate	100 kg	42.63	100 kg	42.63
Transport to farm	$1.00/50 kg/bag	4.00	$1.00/50 kg/bag	2.00
Pesticides				
Carbaryl 85WP	1.5 kg x 4 app	91.38		91.38
Copper Oxychloride	0.5 kg x 4 app	6.88		6.88
Mancozeb 80WP	1 kg x 4 app	26.04		26.04
Dimethoate 40 EC	0.4 ml	4.40		4.40
Sulphur 80WP	0.5 kg/ha	1.60		1.60
Transport to markets	$0.50/20 kg	500.00	$0.50/20 kg	250.00
Total Variable Costs		576.85		462.43
Gross Margin		1243.15		537.57

*In Zimbabwe dollars.
**Manure used was not costed.

Table 28. Budget per hectare of peas at Mutambara.*

	Suitable Soil		Restricted Soil	
	Quantity	Cost ($)	Quantity	Cost ($)
Yield (t/ha)	1.80		.90	
Price/t ($)	400.00		400.00	
Gross Income ($)	720.00		360.00	
Seed	$1.00	50.00		50.00
Fertilizer**				
Compound S	150 kg	89.60	100 kg	44.80
Ammonium nitrate	100 kg	40.60	100 kg	40.60
Transport		5.00		4.00
Total Variable Costs		185.20		139.40
Gross Margin		534.80		220.60

*In Zimbabwe dollars.
**Manure used was not costed.

Table 29. Budget per hectare of sugar beans at Mutambara.*

	Suitable Soil		Restricted Soil	
	Quantity	Cost ($)	Quantity	Cost ($)
Yield (t/ha)	1.80		.90	
Price/t ($)	935.00		935.00	
Gross Income ($)	1783.00		811.50	
Seed	10 kg	42.50	10 kg	42.50
Fertilizer**				
Compound D	200 kg	61.12	100 kg	35.56
Ammonium nitrate	100 kg	40.60	100 kg	40.60
Transport	$1/bag	5.00		4.00
Total Variable Cost		149.22		122.66
Gross Margin		1622.78		688.90

*In Zimbabwe dollars.
**Manure used was not costed.

Table 30. Crop rotations on Mutambara for five major crops.

Crop	Plot Size (ha)					
	.2	.7	1.0	1.2	1.7	2.0
	%					
Summer						
Maize	80	65	50	50	35	20
Cotton	20	35	50	50	65	80
Winter						
Tomatoes	40	40	40	40	40	40
Peas	20	20	20	20	20	20
Sugar beans	40	40	40	40	40	40

The gross margins for plot sizes from .2 ha to 2.0 ha for plots on restricted soil are shown in Figure 8. It is only on 2.0-ha plots that gross margins for crops grown on restricted soils are greater than the Universal Poverty Datum Line of $1,680. The percent increase in yields required for gross margins to equal the UPDL are presented in Figure 9. If an income objective of gaining an income level equal to the UPDL were to be taken seriously, not only would plot sizes have to be increased, but also productivity would have to increase sharply, and an effective program of cost control would have to be instituted. Similar information for the plots on suitable soil is presented in Figures 10 and 11. In these plots, the situation looks somewhat better, but minimum plot sizes would have to be nearly 1.0 ha to meet an income objective of UPDL. Even if such an income objective was met, the payment capacity of the farmers on the scheme would be very limited. If an income objective such as ARDA's (two times the UPDL) was imposed, the difficulties would be severe.

Because Mutambara is a community-managed scheme, it is unlikely that plot size could be increased enough to meet both an income objective similar to the UPDL and to give farmers enough payment capacity to justify (in a financial sense) sizeable investments or significantly higher O&M costs. Unless productivity can be increased sharply, any financial or economic justification of a significant rehabilitation would have to be based on the off-site value of more efficient water use on the Mutambara scheme. (This issue is discussed in the section below.) The rehabilitation of the Mutambara scheme could also be justified solely based on increasing the plotholders' incomes, but the subsidy to the Mutambara farmers would have to be considerable.

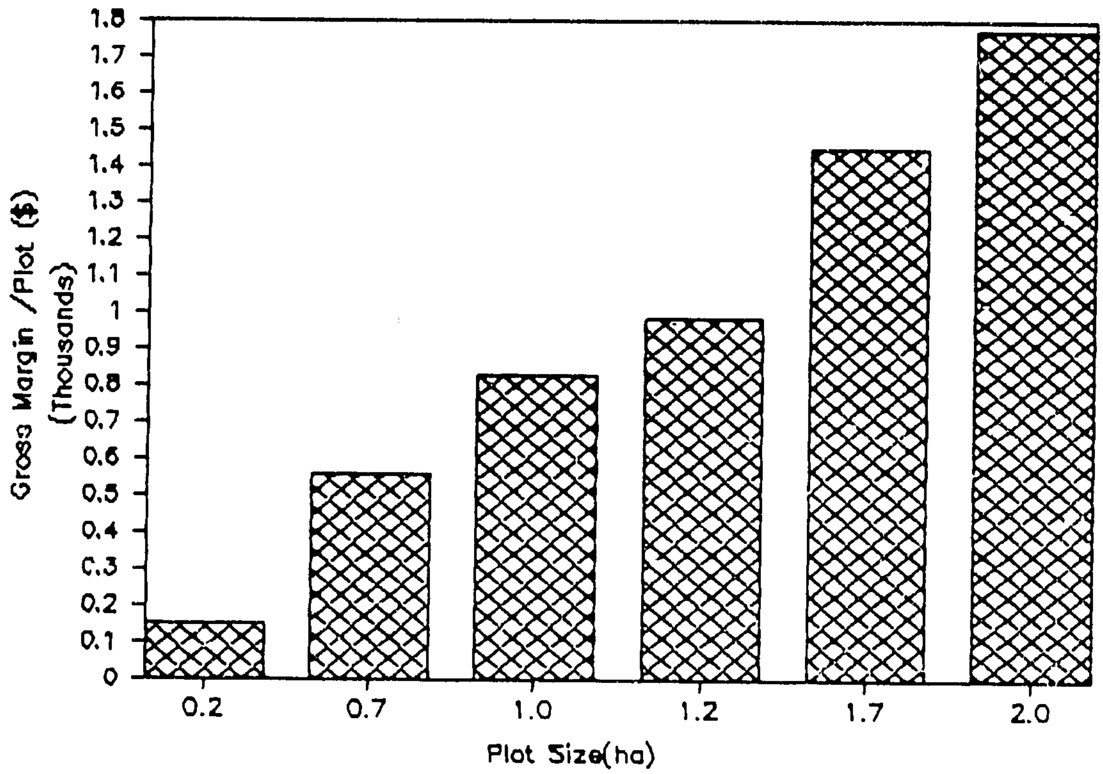


Figure 8. Plot size and gross margins for crops grown on restricted soil in Mutambara.

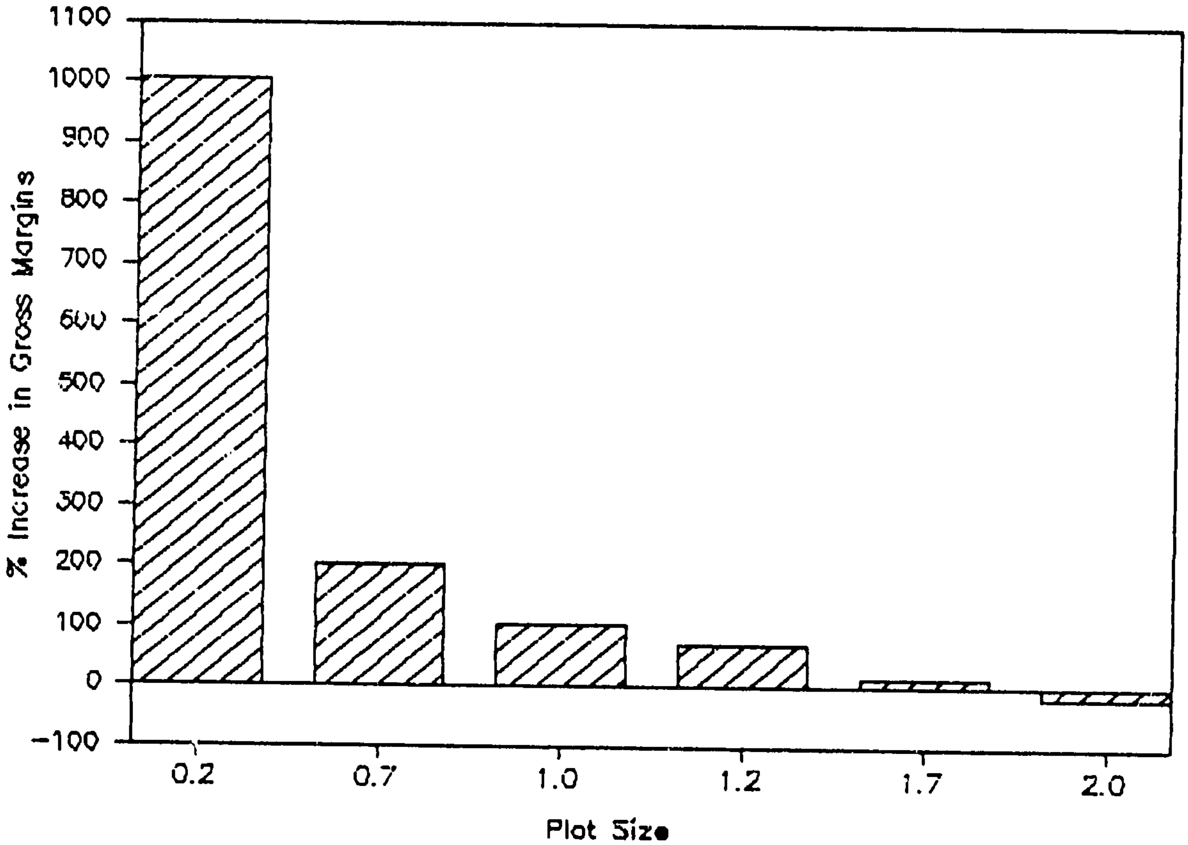


Figure 9. Percent increase in gross margins required to reach UPDL for crops grown on restricted soil in Mutambara.

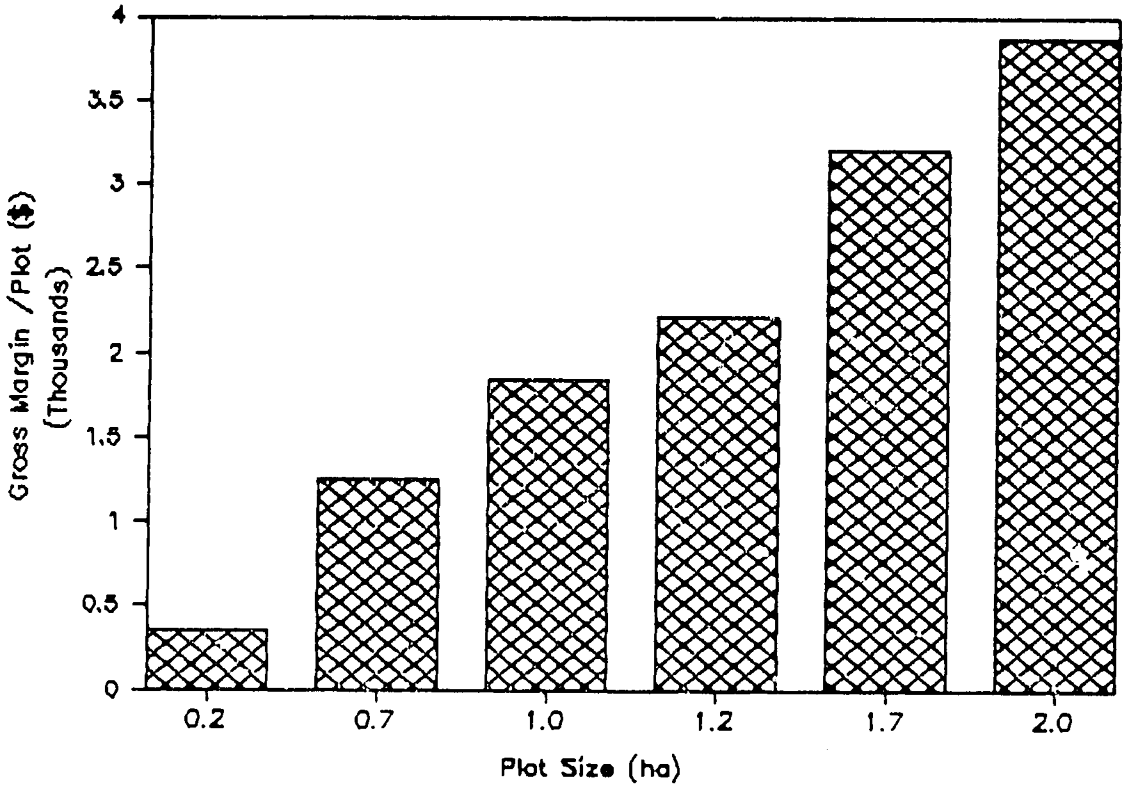


Figure 10. Plot size and gross margins for crops grown on suitable soil in Mutambara.

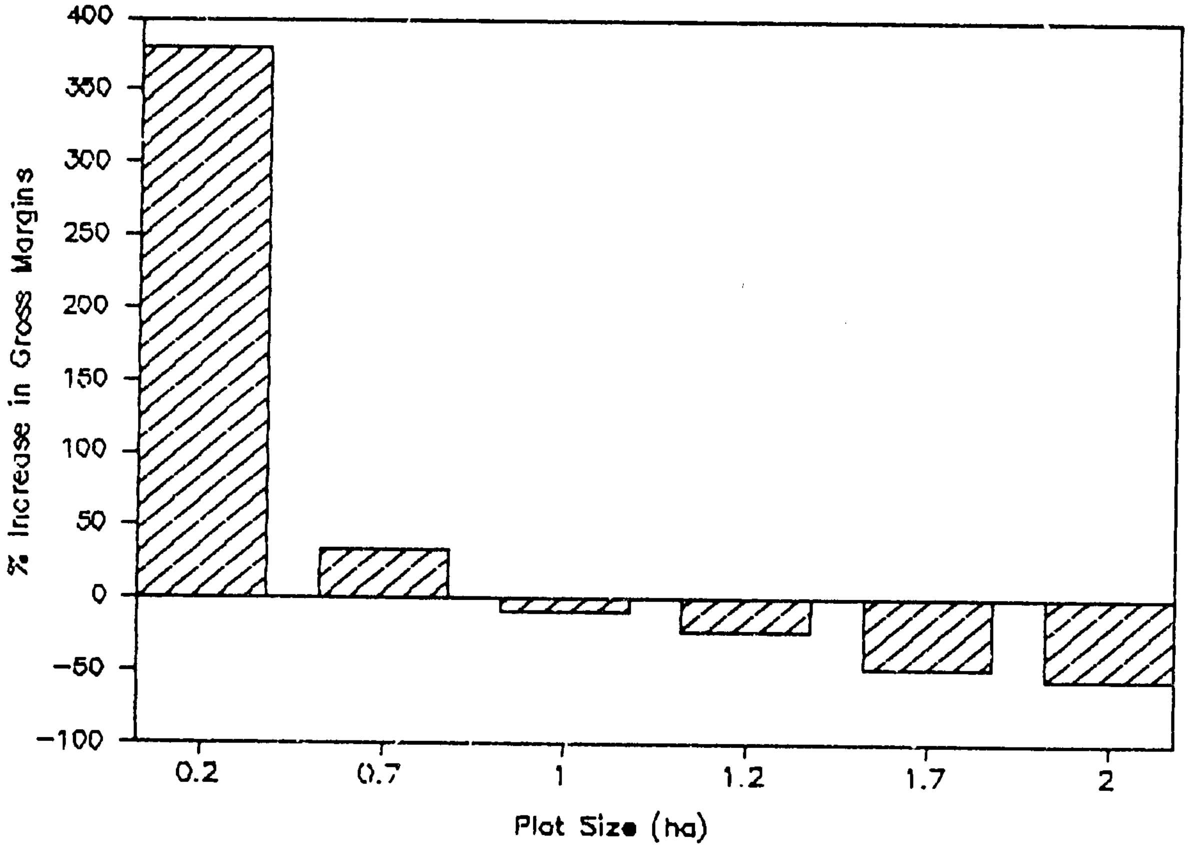


Figure 11. Percent increase in gross margins required to reach UPDL for crops grown on suitable soil in Mutambara.

3. The Value of Water on the Mutambara Scheme

The estimated overall irrigation efficiency of the Mutambara scheme is low -- only 17 percent. Because of this, the estimated gross diversions are high. If water requirements were to be met, the gross diversion would have to be 22,000 m^3/ha during the winter and 18,000 m^3/ha during the summer. Even if the water were available, it would not be possible to deliver that volume of water using the current distribution system. The low irrigation efficiency is one of the reasons that crops at Mutambara receive inadequate water and the yields are low. The gross margin per 1,000 m^3 of gross diversion on a .7-ha plot would be less than $14.00 on restricted soil and only $31.40 on suitable soil. If the irrigation efficiency could be increased from 17 percent to 34 percent the situation would change significantly. It is likely that yield and gross margins on Mutambara plots would increase significantly as more water became available to the crops.

4. Hydraulic and Organizational Structure, Water Pricing, and Water Conservation

> "Excessive water use is the major problem on the [Mutambara] scheme. It results not only from irrigation of unsuitable soils, but also of losses from unlined sections of the main canal, losses from unlined and poorly maintained distributaries, and losses caused by inefficient irrigation on land that is poorly leveled...
>
> Rehabilitation of [Mutambara] scheme infrastructure to reduce excessive water use, producing net savings of between 125,000 and 627,000 m^3 a year, could allow irrigation of a further 8 to 42 ha in the Save Valley." (GOZ, 1985)

Most of the benefits from rehabilitating the Mutambara scheme would be the result of conserving water so that the water saved could be used at other locations in the Save Valley. Therefore, decisions about rehabilitating the Mutambara scheme will significantly affect how a crucial question is answered: "How should Zimbabwe's irrigation water be allocated so as to be of greatest social benefit to the country?"

As with all complex issues, decisions must be based on the best judgment of people who rely on their experience and the best information available -- often supplemented by specially designed research and administrative studies. There are no easy operational answers to this question, and no attempt is made in this report to present easy answers. However, this report does present some general principles that need to be adhered to in regard to the Mutambara scheme if decisions are to be effective.

Because most of the benefit of rehabilitating Mutambara will occur off-scheme, it seems appropriate that the government, rather than the farmers on the Mutambara scheme, accept the major financial responsibility for rehabilitating the scheme. However, an important warning must be issued based on the possible dangers of government involvement in either the rehabilitation or the development of community-managed schemes such as Mutambara.

When governments have become involved in rehabilitating farmer- and community-managed schemes elsewhere in the world, the scheme often becomes a government-managed scheme. The results of such a transformation are as follow:

* Farmers lessen their commitment to the scheme and contribute fewer resources to the operation and maintenance of the scheme.

* Government recurrent costs increase. These costs often cannot be met by governments that face increasing demand for limited public funds.

* Too often, what were once viable community-managed schemes become failed government schemes.

In addition, if the government cannot develop a viable approach for a specific scheme such as Mutambara, the government will not be able to develop a viable methodology for an effective long-term program to encourage the development of new and expanded small-scale irrigation schemes.

These problems can be avoided if a means is found to interject the needed technical assistance and some critical external resources, while at the same time strengthening the community management capabilities. The government must resist the temptation to impose agency control over all details of a scheme receiving assistance from an agency. In no place in the world has the above approach come about accidently. It is the result of appropriately designing programs that include selecting and training agency personnel who are committed to making such an approach succeed.

This issue seems particularly important given the history of the Mutambara scheme and the opportunity the scheme provides to develop a model that could be used elsewhere in Zimbabwe. We do not argue that such a model should be used in all situations in Zimbabwe. In cases where high development and recurrent costs are involved, and virtually all of the benefits occur on the scheme, high levels of production are required for a scheme to be financially viable. At the current time, farmer discipline on some community-managed schemes may not be great enough to insure such levels of production. However, in many other cases, community-managed schemes can be effectively rehabilitated and developed, if the financial responsibility of scheme farmers is kept within reasonable limits.

General Principles. Farmers on a scheme often have little or no appreciation for the off-scheme benefits of conserving irrigation water. However, water conservation may be of significant importance to the country. This certainly appears to be the case in the Save drainage system.

When such a situation exists, the objective should be to develop programs and incentives which make the interests of the scheme farmers and the country congruent. The general principles that should characterize such an approach are presented below.

a. More reliance should be placed on incentives that will help government and the farmers achieve their basic objectives. It is often suggested to price water so that water users are rewarded for conserving water. The idea of using prices to guide water allocation is sound in principle, but difficult to make operational on irrigation schemes with many small plotholders. There are modified volumetric pricing systems that can work for schemes such as Mutambara. One such system is presented on page 115.

b. Investments and recurrent costs should not exceed the benefits each party (government and scheme farmers) will realize. Comparison of benefits and costs must not only be made on an economic basis, but also must be based on cash flow and finances.

c. Because of the limited cash flow of the scheme farmers and their associated farmer organization, farmer investment should emphasize in-kind contributions to the extent feasible, with one objective being to limit financial indebtedness. Emphasis must not only be placed on developing least cost options, but emphasis must also be placed on developing least-cash cost options.

d. The "span of control" of hydrologic and organizational elements must be congruent. That is, the physical control structures in the irrigation system must correspond to the various levels of farmer organization. For example, the farmer organization should include all of the plotholders receiving water from a single distribution canal, but should not include plotholders served by other distribution canals.

e. Effective farmer involvement at the earliest possible stage can result in (1) substantive contributions to the design, implementation, operation, and maintenance of the scheme; (2) strengthened farmer identification with the scheme and a more effective farmer organization; and (3) mobilizing community resources, which can lessen the cash outlay required by government for implementation, operation, and maintenance.

f. In concert with the physical and organizational rehabilitation of the scheme, a farmer and committee educational program must be implemented that will encourage farmers to make effective individual and group decisions. Agency personnel must also be trained to encourage farmers to make such decisions.

g. The design and implementation of scheme development and rehabilitation must simultaneously consider the technical, organizational, financial, economic, and social issues involved in the continued operation and maintenance of the scheme.

A Suggested Approach to the Mutambara Scheme. The brief outline which follows is presented as a basis for beginning to design a program for the Mutambara scheme. Before such a design could be implemented, many details would have to be worked out to make the design site-specific. It may be most practical to implement such a program in phases for financial reasons and to learn from experience on the scheme.

a. The main supply canal will need to be repaired to the extent necessary to control flow and to allow the measurement of flow into distributary canals. It will be necessary to rehabilitate the existing night storage reservoir and/or construct an additional night storage reservoir. The distributary canals need to be lined and control gates to the farm supply canals need to be provided. Farm supply canals need to be shaped and aligned, but little lining may be required at this stage. The physical rehabilitation of the system can take place in stages for financial and management purposes.

b. A hierarchy of water user associations (WUAs) may need to be established. The simplest structure would be the scheme irrigation management committee, and a water users association for each distributary canal. A farmers' organization may be required at the distributary canal level since it is proposed that water be measured volumetrically to determine water charges. Depending on the number of farmers served by a distributary canal, it may or may not be useful to formally organize farmers on each farm supply canal.

c. Criteria need to be established to determine what land will be served by the scheme. Boundaries of the scheme may need to be adjusted so that suitable illegal expansions could be brought into the scheme. Some existing plots on poor soil may need to be excluded from the rehabilitated scheme.

d. Scheme size and water rights need to be balanced, and added water rights may need to be finalized.

e. The irrigation management committee would need a predictable cash flow to repay loans and to fund recurrent costs on the scheme. WUAs on the distributary canals would need a limited cash flow.

f. Charges for water should be assessed per hectare and are referred to here as "land charges." The charge for land commanded by a specific distributary canal would depend on the average amount of water per hectare delivered into that distributary canal (hence the need for volumetric measurement of water flowing into the canal). The land charge would have two components: a fixed charge for a "base level" of water and a charge per 1,000 m^3 for water in excess of the base level. The base level would be the amount of water needed to get good yields if the water was efficiently used within the distributary system and in the field. A schematic of such a water pricing system is presented in Figure 12.

Water use in excess of the base level would be "priced" at a high level. In this way, to avoid the increase in the land charge, farmers would have incentive to have high irrigation efficiencies at the field level and they would also have incentive to work with their water users association and IMC to make certain that the irrigation system used water efficiently. The base charge is designed to elicit necessary farmer financial support for the scheme, while the extra charge is designed to encourage water conservation. The pricing system could be phased in over a period of years. The phasing should include adjusting both the value of the extra charge and the value of the base level of water.

g. An educational program would have to be developed so that farmers could understand the factors in the field and in the irrigation system that influence the amount of water used on the distributary canal.

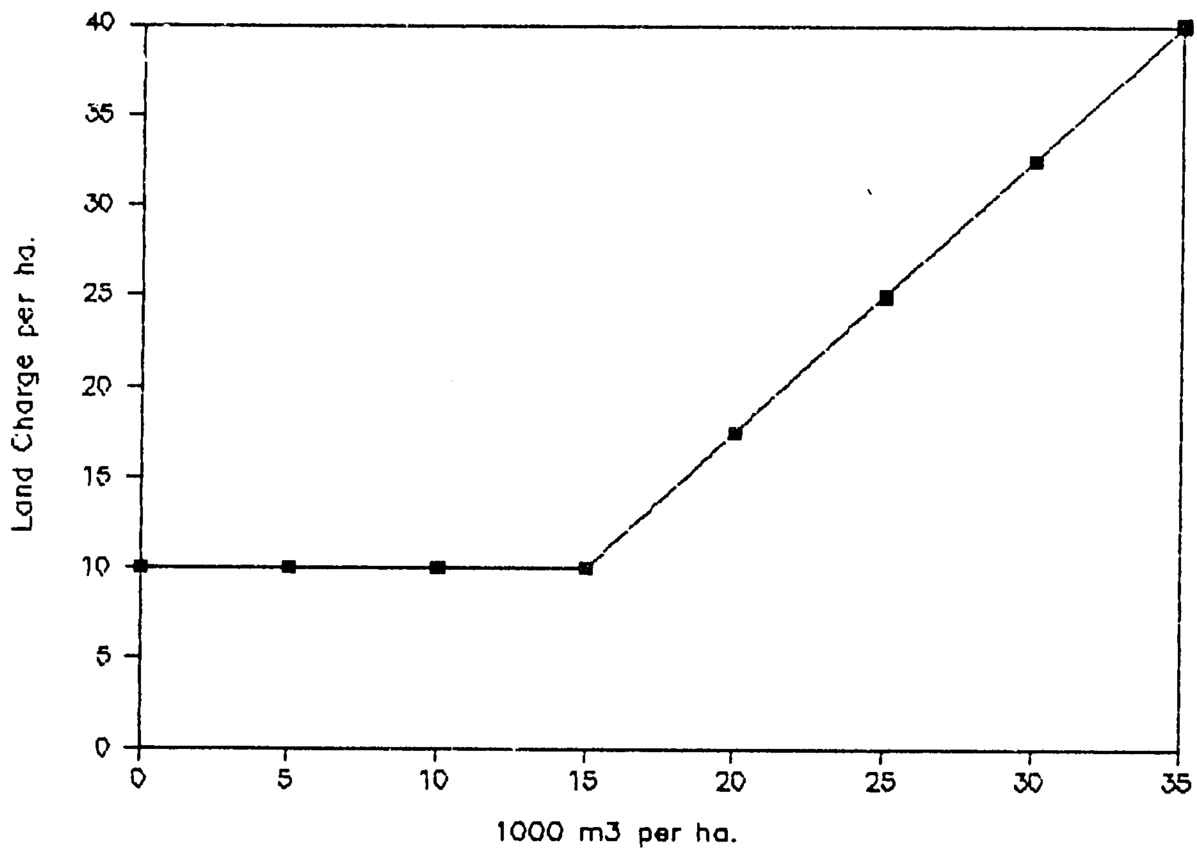


Figure 12. Schematic of water pricing system.

5. Conclusions

Despite the low yields and low gross margins on Mutambara, its continued existence with little, if any, direct subsidy is clear testimony to the effectiveness of the irrigation scheme in terms of serving the goals of the local people. If we used this test elsewhere, we would have to seriously question the effectiveness of many small-scale irrigation schemes in Zimbabwe, since their sustainability is in doubt.

However, at current levels of productivity, it is doubtful that a major rehabilitation program at Mutambara could be self-financing given on-site benefits only. However, the off-site benefits of increased irrigation efficiency on Mutambara are likely to be significant. An appropriate method of charging for water on schemes like Mutambara needs to be developed. Such a method could be used to assist in simultaneously achieving the objectives of the Mutambara farmers and of those officials who seek the most effective use of Zimbabwe's water resources.

G. SYSTEM STRENGTHS AND WEAKNESSES

1. Strengths

Self-Reliance. The Mutambara community has a long history of self-reliance. This is what keeps the scheme operational.

The IMC. The irrigation management committee is well recognized, and farmers expect the IMC to run the scheme.

Freedom of Speech. The community encourages freedom of speech on all issues affecting farmers.

Water Supply. There is an adequate and reliable supply of water to the scheme from the Umvumvumvu River, which is delivered cheaply by gravity.

Crops and Markets. The scheme grows a variety of crops and has easy and ready access to markets.

Rural Incomes. The scheme has contributed to rural incomes in the area, and has provided food security in times of drought.

2. Weaknesses

Water Distribution. There seems to be inequitable water distribution in the system for a variety of reasons (the complexity of the delivery system, poor control of water delivery system).

Physical Structures. There are no measuring structures of any form in the system. The delivery structures are either inappropriately designed or, as in most cases, non-existent.

Maintenance. There are high water losses along the sub-main canals, and the level of maintenance is generally very low.

Input Use and Extension. There seems to be limited use of inputs and low adoption of high yielding varieties. Most farmers indicated that they had had very little extension.

Land. There are only 100 ha of high quality irrigable land interspersed with potentially less suitable irrigable lands. This complicates management. In such a scheme with low extension input, the net result is usually low productivity.

Night Storage Dam. The night storage dam next to the substation was heavily silted and under-utilized.

Operations. There was inadequate data on all of the operations.

Irrigation Schedule. There was no defined scheduling of irrigation, and some farmers were uncertain and unsure about when they would get their next supply of irrigation water.

V. NGONDOMA IRRIGATION SCHEME

A. INTRODUCTION

The Ngondoma Irrigation Scheme was started in 1968, with one of its main objectives being to produce food in a fairly dry region. The scheme is 72 km by road from Kadoma and lies 4 km south of the now defunct Empress Mine. The initial areal extent of the scheme was 10 ha with 12 plotholders, but it was expanded to 50 ha in the early 1970s. In 1979, however, the area was reduced to the current 22.5 ha due to a shortage of water caused by diverting water to the mine.

Ngondoma Scheme has 62 plotholders whose holdings range from 0.1-0.6 ha. AGRITEX administers Ngondoma Scheme. Plans have been made to extend the scheme an additional 16 ha. A plan for the scheme including the proposed extension is shown in Figure 13.

Water for the scheme comes from the Ngondoma Dam on the Ngondoma River. The dam belongs to the Ministry of Energy and Water Resources Development (MEWRD) and was primarily developed to serve the Empress Mine. Now that the mine is out of use, the scheme can apply for more water to irrigate the proposed extension.

Water from the dam is diverted by gravity into a 200 mm pipe and then into a lined and fenced rectangular canal able to convey 90 L/s. This canal is 5 km long and delivers water to a night storage dam upstream of the scheme.

Summer crops are mainly maize and okra, and winter crops are sugar beans and vegetables. A unique feature of the scheme is its water supply -- it is inconceivable that the scheme could run out of water, unless an alternative use for the water is found or the mine reopens. Also, the cropping pattern is geared towards vegetable crops. The scheme is relatively small and can be easily understood and managed.

B. THE PHYSICAL SYSTEM

1. Hydrology

The only water source for the Ngondoma Irrigation Scheme is the Ngondoma River. The river is dammed at the Empress Mine, about 5.8 km upstream. The dam has an estimated capacity of about 7.5 million m^3.

The Empress Mine has been closed since 1985. When the mine was operating, the competing water uses were for mine operation, the Ngondoma scheme water supply, domestic water, and water uses downstream from the scheme.

The scheme's water right entitled it to an allocation of about 382,000 m^3/yr. The mine was allocated 2,905 million m^3/yr, and 0.099 m^3/s had to be released for downstream uses. Since the mine closed, the dam capacity has become available to the scheme and any other prospective water uses.

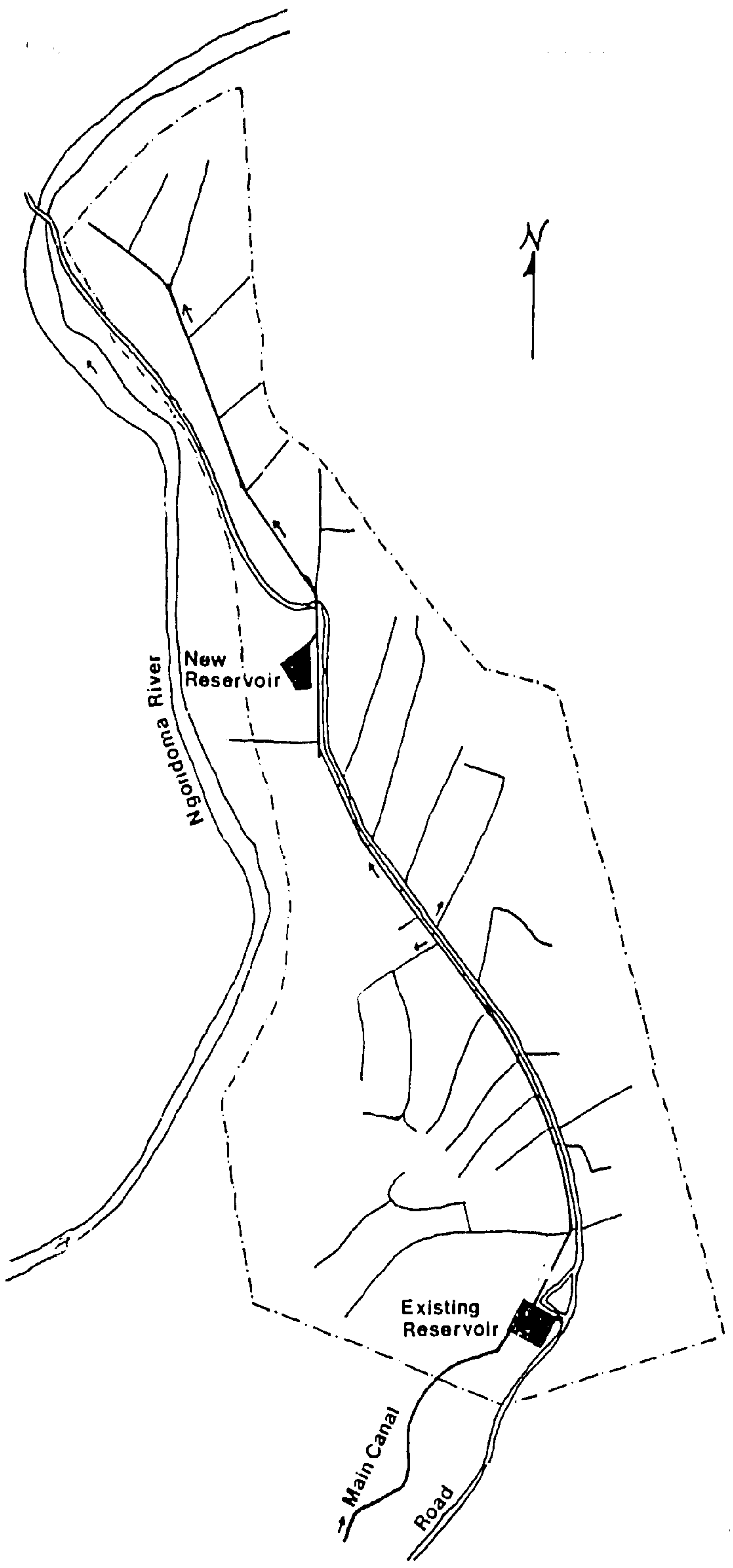


Figure 13. Ngondoma scheme.

The Ngondoma River has a catchment area of 1,000 km^2 upstream of the MEWRD measuring point at the Dam. About 80 percent of the water released at the Ngondoma Dam reaches the night storage dam at the scheme. The design canal capacity is set at 90 L/s. This capacity is being increased to facilitate the planned rehabilitation and extension of the project to a total area of 38.5 ha.

The size of the conveyance canal and the capacity of the night storage dam would limit water deliveries to the expanded scheme. The capacity of the night storage dam is affected by silt deposition. Its capacity at the time of our visit was estimated to be about 4,950 m^3.

If the Empress Mine stays closed, water availability for the scheme and any other prospective uses will not be a problem. In fact, an excess capacity would be available to bring more area under irrigation, depending on the suitability of land for cultivation.

2. Soils

Soils are predominantly reddish-brown sandy loams overlying sandy-clay loam and sandy clay (GOZ, 1986). Soils are fairly permeable, and where there is sufficient depth, adequate waterholding capacity makes these soils suitable for irrigation. The waterholding capacity of these soils has been estimated as 12.5 percent (GOZ, 1986).

Rough pH measurements revealed a range of 6.0-6.8 throughout the area and down through the soil profile. In the absence of soil analysis, it is difficult to estimate soil fertility. The pH range observed would, however, make applied nutrients available to crops.

On the south end (from the existing night storage dam), the soils are more than 100 cm deep. At about 60 cm, soil color changes from reddish-brown to a lighter color. The lighter colored soil may be more porous than the darker soil, though no measurements were taken on this aspect. Gravelly soil starts at a depth of about 120 cm.

Soils north of this region (from about the area occupied by houses and offices to the end of the current irrigated area) are the same texture as above, but shallower before hitting gravelly soil (not more than 60 cm). This soil type continues into the proposed extension area, and gradually the soil depth increases to more than 120 cm before gravelly substrate occurs.

3. The Physical System

The Ngondoma irrigation scheme was established in 1968 in conjunction with the water supply established on the Ngondoma River for the Empress Mine. The Ngondoma Dam is an impressive structure in good condition with a capacity of 7.5 million m^3. The dam is earth and rock fill, with a concrete and rock spillway equipped with counterweighted gates. The spillway empties into the original river channel.

The irrigation water is released from the dam into a rectangular brick and cement-lined channel 0.7 m wide and 5.8 km long. The channel is in good condition, though it does lose some water. The supply channel has five inverted pipe siphons to convey water under roads and other obstacles. The capacity of the siphons was not determined.

The water from the canal is discharged into a night storage dam. The capacity of the dam is estimated to have been reduced from 8,900 m^3 to 4,950 m^3 due to sedimentation. The night storage dam is equipped with a pipe spillway and a gate valve to control flow into the supply canal. The gate valve has been replaced recently and is in good condition.

The supply canal is concrete-lined and is trapezoidal in cross-section. The supply canal has drop structures; some with plunge pools to dissipate energy from the larger drops. Water is retained in the plunge pools, which could constitute a health hazard from water snails carrying schistosomiasis. The turnouts are equipped with steel slide gates, most of which are in place. The gates were in good condition, although some of the gates were reported to be difficult to operate. The supply canal is 1.25 km long, is in generally good condition, and shows evidence of repaired cracks in the concrete. Some of the distribution canals are lined; the larger ones being trapezoidal in section, while the smaller ones are rectangular. These channels are generally short, less than 100 m, and some are in need of maintenance. There are no measuring structures of any kind on the system.

The system is supplied with natural drainage to the Ngondoma River. The surface drainage appears to be adequate on the scheme. There are some low spots in the fields, and the system would benefit from land leveling.

Discussion with AGRITEX officials and the scheme manager indicated that the area irrigated during 1970-74 and subsequently abandoned is under consideration for system expansion. After inspecting the proposed area, it was apparent that the "expansion" is in fact a rehabilitation. Some of the original lined channels are in place, while other sections need relining. The unlined sections of the distribution canals need to be reformed, and the brick and cement drop structures rebuilt. It would appear that relatively little effort would be required to bring the area under irrigation.

It has been proposed that the rectangular main canal have its side walls raised in some locations to increase its capacity to carry water from the dam. Although supposedly in progress, no evidence of construction was seen. However, the existing capacity of the main canal appears adequate to handle the proposed increase in irrigated area. The capacity of the inverted siphons to handle the increased flow needs to be checked.

C. THE SOCIAL/INSTITUTIONAL SYSTEM

1. History

According to previously published reports (GOZ, 1986), the Ngondoma Scheme contained 12 farmers on 10 ha of land in 1968 when the scheme began operating. The current AGRITEX irrigation manager arrived in 1975, after the scheme had expanded to 50 ha and then shrunk to under 20 ha. At that time, the scheme was not producing well. There were 17 plotholders, but many farmers stayed only one season, became discouraged, and left. The extension worker recalls that, when he arrived in 1975, only one Ngondoma farmer owned a scotch-cart (ox-cart).

During the late 70s, better management and increased farmer irrigation knowledge improved the scheme's productivity. The number of farmers increased and the scheme expanded to its present 22.5 ha. Currently, almost all plotholders own cattle, and there are 80 dryland farmers reported on a waiting list to settle at Ngondoma. The extension worker stated that compared to 12 years ago, "the farmers are now rich."

2. Social Structure

There are currently 62 plotholders at Ngondoma, most of them from Chirumanzi District, approximately 200 km away. An estimated 10 percent of the plotholders are women.

Farmers wishing to settle at Ngondoma must first submit an application. Local AGRITEX officials and farmers from the irrigation management committee then check the applicant's background.

Though the "first come, first served" rule applies, there are other important selection criteria. Farmers with some capital are considered, but committee members report that preference is given to dryland farmers with small plots of land who can truly be helped by farming at Ngondoma. Lower priority is given to master farmers who farm larger plots of dryland, as benefits to them would not be so great. Committee members also prefer farmers who have no outside business interests. Compared to other schemes in Zimbabwe, settler selection at Ngondoma appears to be based more heavily on need rather than on the potential agricultural contribution an applicant could make to the scheme.

Plot sizes at Ngondoma range from 0.1 ha to 0.6 ha. Previously published material (GOZ, 1986) indicates that most of the plotholders farm either 0.1-ha (later settlers) or 0.6-ha plots (earlier settlers), with 80 percent of the 22.5 ha made up of 0.6 ha plots. If the scheme is expanded, farmers feel that earlier settlers should be given more land first, before new settlers are allowed to farm. Ngondoma farmers said that "since the sadza (cornmeal, local staple food) is in front of us, not outside people, we should be served first." AGRITEX's official policy is to give land to new farmers if AGRITEX irrigation schemes are expanded.

Some farmers feel that they own their Ngondoma land, though they recognize that AGRITEX holds title to the land and they could be evicted for violating the scheme rules. In essence, farmers pass on their plots to their children, though no formal, legal titles change hands.

Many of the farmers have scattered plots on the scheme; i.e., a 0.1-ha plot at one location and a 0.5-ha plot at another location. This scattering of plots made managing the scheme easier during a 1977 drought. At that time, AGRITEX instituted a proportional reduction in land irrigated for each farmer.

Some plotholders continue to retain dryland holdings outside of Ngondoma. Many of the very early settlers have outside employment, such as teaching. More recent settlers usually have no employment other than farming.

3. The Irrigation Management Committee and Local Organizations

There is an irrigation management committee at Ngondoma. Committee members said that its purpose is to assure adequate water delivery to the farmers, promote harmony, enforce the scheme's rules, and resolve petty disputes. One farmer stated that the IMC also "formulates and legislates" the rules. Another said that its purpose is to gradually take over responsibility for the system from AGRITEX's irrigation manager.

Every year the farmers elect seven plotholders to serve on the committee, including a chairman, secretary, and treasurer. All plotholders are eligible to vote, and AGRITEX does not interfere in these elections. The extension worker, however, does oversee the voting and counts the ballots.

When the JFW team met with the IMC, five of the seven members were present, including two female members. Two of the current seven members (the chairman and the treasurer) have been at Ngondoma since 1968. The scheme's rules are drafted by the plotholders and the IMC and are written and recorded in a book, along with other committee business. Farmers who consistently break the rules are evicted from the scheme. Farmers recalled that a plotholder was evicted in 1984, but only after committee members had repeatedly warned him.

The rules are very specific and contain exact fines. Some examples of Ngondoma rules are as follow:

1. If cattle eat maize inside the scheme, the owners will be fined $0.30 for each plant consumed.

2. Farmers must use authorized gates to enter the scheme. Any farmer entering the scheme through the security fence, rather than the gate, will be fined $0.50 for each strand of wire in that fence.

3. Owners of stray cattle in the scheme are fined $1.00/day.

4. Cattle are allowed to graze on fields after they have been plowed, but not before.

5. Since farmers use canal water for drinking water, there is a $5.00 fine for anyone caught bathing in the canal.

6. After 6:00 p.m., no one should be seen on the scheme.

7. To keep the canal clean, owners of dogs running loose on the canal are fined $5.00.

While talking with committee members, the JFW team saw an example of how these laws are observed: a woman walked along the canal with her dog; the dog was on a short leash.

The IMC has also arranged with AGRITEX that if the water bailiff is not available to operate the system due to illness, on weekends, or after hours, committee members have the authority to open and close gates to allocate water. The committee helps to determine how much each plotholder should contribute to purchase siphons for the scheme. The committee represents all the farmers in marketing decisions and makes a group purchase of agricultural inputs. The committee also collects the maintenance fee of $145/ha each year from each plotholder and gives the money to AGRITEX. Plotholders are allowed to pay their fees in one lump sum, or to pay most of it in the summer and the remainder in the winter. Because of this flexible arrangement, all farmers reportedly pay their maintenance fee.

After collecting the funds, the IMC presents the money to an AGRITEX clerk, not to the extension worker. The money is not given to the clerk, however, unless the clerk has his receipt book. The IMC members are emphatic -- no "records," no funds.

The committee has also adopted unique rules for plotholders who pay their maintenance fee late. Years ago, a late payer claimed that he personally took his maintenance fee to the provincial capital of Gweru and paid it there. Many farmers did not believe him and wanted him evicted. To avoid such confusion, the committee decided that all maintenance fees must be given to the IMC, even if payment is late. If a plotholder is very late in making his payment, he must also buy the committee member a round-trip bus ticket to Gweru, so that the committee member can officially make the payment.

The IMC officers have received training from AGRITEX. Separate trainings sessions have been held for chairmen, secretaries, treasurers, and all officers combined. Subject matter has included committee responsibilities, water management, organizing meetings, and imposing discipline.

The Ngondoma irrigation committee appears to run the scheme firmly and seems to possess a significant degree of power. The committee members appear to take their responsibilities seriously. There are formal, written rules for the scheme, and anyone can examine the committee's records. Members know their individual responsibilities and seem to carry them out effectively.

There is at least one other local farmers' organization at Ngondoma -- a savings club. This informal group was founded to hire effective transportation to get the farmers' produce to markets. Each plotholder was asked to contribute $14 to the savings club, but only $300 has been collected so far. Farmers are reluctant to contribute to this organization.

D. CHARACTERISTICS AND PERFORMANCE OF SYSTEM MANAGEMENT

1. Water Supply, Distribution, Allocation, and Application

Water is supplied to the scheme from the Ngondoma Dam. A gravity canal conveys water from the dam into a night storage reservoir at field-edge. During the study, the flow was 29.7 L/s at the outlet of the first siphon and 26.2 L/s near the entrance to the night storage reservoir. The estimated night storage dam capacity of 4,950 m^3 appears to be 55 percent of design capacity due to siltation.

Conveyance losses were estimated at 0.35 percent per 100 m giving a conveyance efficiency of 80 percent. The losses were due to leaks at the siphons and also in the drain culverts.

The distribution system from the night storage reservoir had water losses of 0.83 percent per 100 m. Losses in the laterals were not considered significant due to their short length and relatively good condition, although some laterals needed maintenance. Distribution efficiency was estimated to be 83 percent. No field application efficiencies were measured because no farmers were irrigating during the visit.

Water supply from the Ngondoma Dam to the scheme night storage reservoir is controlled by a water bailiff under the MEWRD. The bailiff works with the extension worker to determine the scheme water requirements and main canal flow from the main dam. Water is supplied on demand. The supply (382,000 m^3/yr) is adequate to meet current irrigation water requirements at Ngondoma.

The AGRITEX water bailiff is solely responsible for allocating water from the night storage dam to individual farmers during a 5-day work week. During weekends, if farmers fail to complete their irrigation during the normal time, water allocation is the responsibility of the irrigation management committee.

Water is allocated to each farmer for 8-10 hours (in some instances, up to 12 hours) every 7-8 days, according to design. Although there are 62 plotholders, AGRITEX arranges its irrigation schedule based on 35 0.6-ha plots. As farmers have left Ngondoma over the years, new farmers have been allotted positions on those plots. For instance, if a farmer leaves a 0.6-ha plot, AGRITEX turns that plot into six 0.1-ha plots for six new farmers.

The irrigation schedule depends mainly on the crop and stage of crop growth, with some limitation imposed by the total water delivered from the night storage reservoir. Weekly water allocation is as follows:

1. On days 1, 2, 4 and 5, the first 8 hours of irrigation time are allocated to major crops (maize) and the last two hours to vegetables.

2. Day 3 is allocated to the 0.5-ha plots only. Pre-planting water allocation is on demand, and later irrigations are on rotation. Farmers with small plots normally give excess water to other farmers to reduce waste at the canal exit.

Farmer interviews indicated that water was allocated to 8 farmers, with the total irrigated area being 4 ha/day. Given this information, the irrigation cycle would be 5 to 6 days. However, farmers stated that the dam capacity could not command 4 ha/day in practice. Since the current study was conducted during the off-season, this could not be substantiated.

If the system cannot cope with 4 ha/day, farmer statements suggest that the field application efficiencies are below 50 percent. Calculations indicate that with a peak requirement of 625 m^3/ha at 50 percent efficiency on 4 ha, the total requirement is just in excess of the dam capacity of 4,950 m^3. The reasons may be the inadequacy of the distribution system (capacity and low siphon heads) and field conditions (topography and lengths of run). Therefore, it is suggested tnat the overall project efficiency is about 45 percent.

Water is taken from a lateral to a field using siphons. Generally, farmers use two 25-mm diameter or 50-mm diameter siphon tubes in each furrow. The 25-mm and 50-mm diameter pipes discharge 0.4 L/s and 1.33 L/s, respectively, at a head of 110 mm.

During this study, observations were made on farmer's pre-ploughing irrigation practices. Field conditions were characterized by a furrow length of 82 m, a furrow spacing of 0.6 m, a furrow slope of 1.1 percent, and the use of four 25-mm diameter siphons. Furrows were overgrown with weeds.

The application depth was estimated to be 190 mm with a total volume of 1,900 m^3/ha. The high application was probably due to the cracked soils and too long a lay period (one month). Assuming soil uniformity and status, and similar farmer practices, it would take 10 days to complete the pre-ploughing irrigation with the night storage dam at full capacity at the beginning of each irrigation.

The study is summarized below:

1. There were some losses in the conveyance and distribution system; conveyance efficiency was estimated at 80 percent.

2. The capacity of the night storage dam was significantly reduced by siltation, but the dam could meet water requirements if desilted.

3. The irrigation management committee attempts to maintain and operate a strict irrigation schedule.

4. Overall project efficiency is thought to be below 50 percent, although this estimate was not fully substantiated due to lack of data on field application efficiency.

5. Pre-irrigation tends to exceed the 125 mm determined appropriate for these soils.

6. Some of the water demand for the proposed expansion of the scheme could be met from the present water right if the existing system was improved to save water.

2. Reliability, Adequacy, and Equity of Irrigation Water

Ngondoma scheme lies in one of the higher rainfall areas of Zimbabwe. Two million cubic meters of water per year are available from the annual runoff, at a 10 percent risk as a fraction of mean annual runoff. This volume is considered to yield a secure water supply to the scheme.

Sufficient quantities are released from the night storage dam to satisfy irrigation requirements. No shortages occur in the distribution subsystem unless the inverted siphons linking the main in-field canal and the lateral canals get blocked by plastic bags or other obstacles. This rarely happens, but when it does, irrigators promptly remove the obstacle.

Minor water application problems occur when there are too few siphons used to apply water to the furrows. A shortage of siphons is usually the result of worn siphons not being replaced in time. In such a case, the IMC organizes farmers to make contributions to purchase new siphons.

Equity in irrigation water allocation is achieved by organizing the irrigators in groups that can irrigate only on given days. Each farmer in a group is given a certain number of siphons to irrigate. Generally, 25-30 siphons are given to a farmer for a day's irrigation on 0.5 ha. A chart of the groups, dates and days for irrigation is displayed in the extension worker's office and is closely monitored by the irrigation management committee. Based on field observations, farmer interviews, and the availability of water, it seems that water is equitably distributed.

3. System Management

<u>Farmer Involvement in Irrigation Activities</u>. Ngondoma farmers participate in many irrigation activities. Farmers, in collaboration with the IMC, are responsible for distributing and operating the siphons.

Though only the water bailiff has the authority to open and close the outlet gate on the night storage dam, arrangements have been made with AGRITEX so that the IMC can open or close the gate if the water bailiff is unavailable.

Farmers said that they have good working relations with the local extension agent and with the MEWRD lineman. The extension worker also appears to work well with AGRITEX field workers and the MEWRD lineman. The extension worker stated that he sees the lineman almost every day. These good working relations helped Ngondoma to be placed third in scheme competitions organized by AGRITEX. The competition was based on level of production and effectiveness of committees.

Farmer involvement in irrigation activities has led to other cooperative activities. As mentioned earlier, the farmers buy and manage the siphons as a group and have started a "savings club" to provide adequate transportation to markets. Ngondoma farmers also plan their cropping patterns together in consultation with the extension worker, so farmers can grow crops in a coordinated manner. Also, the IMC pools farmers' resources to buy inputs, which significantly increases the buying power of the group. Additionally, the farmers have contributed labor and money to help AGRITEX repair the security fence around the scheme, even though that is AGRITEX's responsibility.

The farmers themselves are particularly proud of the "neighborliness" that exists between them and nearby dryland farmers. At the end of each growing season, Ngondoma farmers allow the local people to come to the scheme and cut grass for their thatch roofs. The farmers claim that Ngondoma survived Zimbabwe's war of independence because of the good relations with their neighbors.

This involvement and cooperation has given the farmers a strong sense of identity with the scheme. Some farmers claimed that the scheme belongs to the farmers, not to AGRITEX. One farmer was more specific and said that Ngondoma belongs to the government because it pays for the maintenance, but the plots belong to the farmers. The extension worker said that the farmers think that Ngondoma is their scheme, and regional AGRITEX official stated that it is proper that the farmers should feel that they are part of the scheme.

The irrigation committee stated that Ngondoma is the best scheme they know about in Zimbabwe, and that good land and water make it that way. An AGRITEX official asked the committee if Ngondoma was better than another nearby AGRITEX scheme that has 0.1-ha plots and is well-managed. Committee members said Ngondoma is better than this site because Ngondoma farmers must manage 0.5- or 0.6-ha plots. They said that "it is very easy to find a wife that can take care of a one-room house. A wife that can care for a nine-room house, however, is much better."

There are eight or nine AGRITEX field workers at Ngondoma who are responsible for cleaning the canal, cutting the grass, and maintaining the security fence. Although the field workers have no large plots at Ngondoma, they do have small garden plots for vegetables.

The field staff has strict working hours: 8 hours a day, from 7:00 a.m. to 4:00 p.m. The workers claim that they are happy with their work, and always receive cooperation from the farmers. For instance, during peak irrigation times, the IMC may ask the field staff to work longer than 8-hour days. The workers often agree, taking days off later in the season to compensate.

One of the most important AGRITEX field workers is the water bailiff, who helps to ensure equitable water allocation throughout the scheme. He claims that he takes his position very seriously. Otherwise, he said, the plotholders would blame him for inequitable water distribution. Farmers reported that the water bailiff is responsive to their irrigation needs and requests.

All AGRITEX field workers contacted stated that they see no perceived benefit to becoming Ngondoma farmers. They felt they were making more money as government workers than they could make as a farmer. One stated that he could not do his job properly if he farmed more than his small garden plot. He said that farmers do not receive a steady stream of income as he does. He pointed to the now empty Ngondoma fields and said that the Ngondoma farmers must wait until the next crop to receive any money. Though the JFW team's study indicates that some farmers receive a higher yearly income than the workers, the workers feel that they make more money than the farmers.

Farmers and AGRITEX staff were quite willing to discuss what they felt were Ngondoma's strengths and weaknesses. Farmers feel that their good relations with dryland farmers, good soils, and good water have contributed to the scheme's success. They are pleased with their higher incomes and their new ability to send their children to school and to obtain basics such as a scotch-cart (ox-cart). AGRITEX workers are pleased with the farmers' cooperation and the proximity of work to their homes, and they express a high degree of job satisfaction.

There are also perceived weaknesses in the system, however. Farmers feel that their plots are too small, and the scheme needs to expand. Other farmers stated that since the Empress Mine closed, transporting okra further to roads and markets has decreased their returns. AGRITEX officials stated that the major problem at Ngondoma was the need for expansion. Another persistent problem was the poor operating condition of canal gates.

The farmers have a "vision" of Ngondoma's future. They believe that AGRITEX will hand over the scheme to their control one day. However, they feel that they will still need AGRITEX's technical expertise. For instance, though the farmers want the scheme to expand, they feel that they do not have the technical knowledge to construct a new canal or significantly improve the present canal. Committee members stated that if they took over the scheme and made mistakes, the government would not be pleased with them.

The AGRITEX field staff are skeptical that the farmers could take over the system. Since workers feel that they make more money than the farmers, they don't think the farmers could pay field workers an adequate salary. They think new workers would have to be hired at lower salaries.

One regional AGRITEX official stated that AGRITEX schemes under 50 ha could be handed over to farmers, if financial problems could be solved. He stated that currently, neither farmers nor IMC have the capital necessary to make significant improvements on schemes. A possible solution to this problem is to allow the IMC to collect and retain all or part of the $145/ha/year maintenance fee. These fees could be put into a formal farmers' "savings club." After 5 or 10 years, there should be enough savings to finance the scheme. Allowing farmers to control the maintenance fees, rather than AGRITEX, is an idea that has some practical drawbacks (i.e., how will AGRITEX generate revenue?), but it would give the farmers and the IMC greater independence and decision-making powers.

Conflict. Ngondoma appears to have very few serious conflicts. The only reported disputes were with farmers who sometimes let much water run past the end of their furrows. Farmers who do so claim that they need the additional water to thoroughly irrigate their crops. When the IMC members see this apparent over-irrigation, they tell the farmer to stop irrigating. Arguments sometimes ensue if the farmer does not want to stop irrigating. These conflicts, however, do not appear to adversely affect the scheme's performance.

4. Scheme Maintenance

Scheme maintenance falls primarily on MEWRD and AGRITEX. Maintenance of the Ngondoma Dam, the main conveyance canal, and the night storage dam is the duty of MEWRD. The maintenance program involves clearing silt, mending or repairing any damaged parts of the canal, cleaning the night storage dam, and cutting the grass in and around the dam. Repairs to the canal are done as and when required. Canal status is checked regularly -- someone walks the whole length of the canal at least once a week. Currently, the canal is in good order.

Maintenance of distributary and farm canals is done by AGRITEX staff, excluding the small portions of ditch between plots. This maintenance involves cutting or burning grass, cleaning the canal, and repairing gates or broken concrete. Repairs to concrete works are those resulting from wear, not from abuse. Farmers pay $145/ha/yr in user fees for maintenance.

Maintenance is normally a post-seasonal activity using local labor. Farmers are happy with the current arrangements for maintenance. In general, the scheme canals are in good order.

E. CHARACTERISTICS AND PERFORMANCE OF THE AGRICULTURAL SYSTEM

1. Crop Rotation

Major crops grown are okra and maize in summer and sugar beans and vegetables (rape, tomatoes, cabbages) in winter. Farmers do not grow cotton (widely grown outside the scheme on dry land) because farmers say the plots are too small for cotton to be profitable. However, they do grow cotton, along with maize, on their plots at their homes. Average yields for dryland maize vary between 500 - 2,000 kg/ha while dryland cotton yields vary between 750 - 1,000 kg/ha.

Maize and okra are planted in July or August and green maize and okra are sold in November. Such an early planting date is possible because Ngondoma does not experience frost during this time and water is available for irrigation. Beans are normally planted at the end of February into early March and are harvested in June. At the time of the study, (mid-February) no crops were in the fields.

The cropping pattern results in few pest problems. For example, maize streak is not a problem because wheat is not grown in winter. However, tomatoes are severely affected by red spider mites, which are possibly transmitted from cotton fields on dryland plots.

2. Fertilization

Table 31 gives the fertilizer rates reported to be used by farmers at Ngondoma.

Table 31. Fertilizer rates reported used at Ngondoma.

Crop	Fertilizer	Application (kg/ha)	When
Okra	Compound D	500	Before planting
	Ammonium nitrate	500	Top-dressing over most of reproductive period
Maize	Compound D or L	500*	Before planting
	Ammonium nitrate	400*	Top-dressing
Beans	Compound D	200	Before planting

*These rates for maize are fairly high and do not appear to be based on soil analysis.

Farmers use certified seed purchased from seed companies to grow okra and maize. For maize, variety SR52 is planted earlier than R215 and R201. No research figures are available for okra. For sugar beans, farmers retain seed from previous plantings as they cannot afford certified bean seed.

3. Crop Water Requirements

No evapotranspiration data was available for the site for the crops grown. However, soil water holding capacity was assumed to be 12.5 percent. Crops are irrigated at about 50 percent moisture depletion, and an irrigation cycle of 8-10 days is followed, assuming about 8 mm evaporation each day. Differences in profile depth may indicate a need for a shorter interval for shallow soils as compared to that for deeper soils. Calculations using a 60-70 cm depth for shallower soils would give a cycle of 4-5 days. Exact determinations need to be done on this aspect.

4. Plant Populations

Table 32 gives plant spacing and populations at Ngondoma.

Table 32. Plant population at Ngondoma.

Crop	Spacing	Plants/ha
Okra*	45 cm between rows; 15 cm within row	140,000
Maize	100 cm between rows; 25-30 cm within row**	33,000-40,000

*Okra is grown on small plots (0.1 ha) because it is labor intensive.
**Planted this way, the maize produces bigger, more marketable cobs.

5. Extension Services

The scheme is under the area irrigation officer, who supervises the extension worker. The resident extension worker, who serves as the irrigation manager, advises on dates of planting, fertilization, and other cultural practices. Farmers do not have credit facilities because the crops grown make loan recovery by lending agencies (i.e., AFC) difficult.

6. Yield

The yield for each crop which is used in the crop budgets is the average yield that is attained on the farm. On average, the yield of green maize is determined by the plant population. Grain yield is the surplus which farmers are unable to sell as green maize.

According to farmers, okra yield depends on fertilization, which is staggered throughout the harvest season. The yield of beans is rather low, and farmers attributed this to the lack of certified seed for beans. Table 33 gives the range of yields obtained during interviews with farmers.

Total production is determined by multiplying the average yield by the hectarage of each crop. Note that the yields used for this calculation were given to us by the farmers (Table 34).

Table 33. Yield of major crops per hectare at Ngondoma.

Crop	Yield Range/ha	Average Yield/ha
Maize (green)	19,000-30,000 cobs	26,000 cobs
Grain	0.4 - 2.0 t	0.9 t
Okra	73 - 138 bags	100 bags
Beans	1.2 - 2.4 t	1.7 t

Table 34. Total estimated production of Ngondoma scheme.

Crop	Area Planted (ha)	Total Production
Maize (green)	18.5	481,000 cobs
(grain)	18.5	16.7 t
Okra	3	300 bags
Beans	19.6	33.3 t

7. Prices and Marketing

The crops grown on the scheme are sold mostly to the uncontrolled market where supply has to match demand if a reasonable price is to be received, since price variation is determined by the amount of produce in the market. Usually, the earlier the crop is brought to market, the higher the price received. However, the converse is usually true for green maize and okra.

Farmers face competition from dryland farmers and commercial farmers in the markets. Initially, farmers were assured of a reasonable price for their commodities from the mines. Currently, farmers face wide variation in prices in a particular season.

Marketing is the major constraint faced by the farmers at Ngondoma. The current cropping pattern originally depended on buyers from the Commoner and Empress Mines. When these mines closed, the farmers were left with the marketing community at Venice Mine, about 50 km from the irrigation scheme. In addition to the Venice Mine market, some dryland farms purchase produce from the farmers on the scheme.

When the going gets tough, farmers tend to turn to the towns further away from the scheme. To sell okra, farmers travel as far as Bulawayo, some 300 km away. However, some private buyers travel to the scheme to purchase produce, especially beans and okra.

A major problem faced by farmers in marketing their produce is lack of transport to market. Farmers use ox-drawn carts to transport their produce to the public transport road. The farmers then use public transport to get to the markets. Farmers would like to be able to transport their produce directly to distant markets by truck, rather than using public transport which limits the amount of goods carried at any particular time. Also, their produce may be separated and put on different buses, causing further trouble for the farmers. Some farmers must hire a vehicle to get their crops to a road or market. Some farmers reportedly take their crops in a wheelbarrow 6 km to the paved road.

F. FINANCIAL AND ECONOMIC PERFORMANCE

Ngondoma is a highly productive scheme largely because the water supply for Ngongoma is very reliable, more than adequate for the potential command area, and equitably distributed because of the organizational and physical structure of the scheme. This situation is possible because the large water source for Ngongoma was built primarily to serve what is now a non-operating mine and because Ngondoma has a relatively small command area with suitable soil.

Ngondoma is also productive because the plotholders have a long history of producing early green maize, which they are able to sell for a high price. In addition, okra, also produced for an early market, was introduced more recently. The AGRITEX person who functions as the scheme manager appears to work well with the strong and well-organized irrigation committee elected by the farmers. Despite the relative isolation of the scheme, Ngondoma demonstrates the potential for intensive irrigated agricultural production in Zimbabwe when the supply of irrigation water is adequate, reliable, and equitably distributed. The farmers are well organized and can assume a great deal of responsibility for operating the scheme, and plotholders are able to make decisions about the crops they will grow based on the profitability of those crops.

1. Ngondoma Crop Budgets

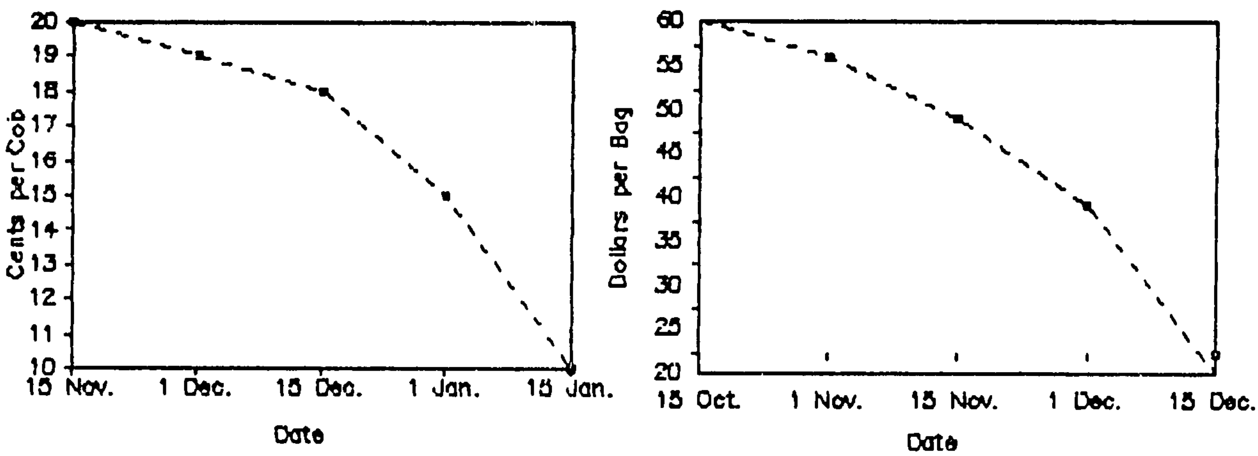
The yields used in the following budgets are the average yields attained on the plots. The major summer crops are maize, which is sold as green maize, and okra. The yield of green maize is largely determined by plant population. The maize valued as grain is late season green maize that is allowed to mature.

Okra yield depends on the fertilizers that are applied throughout the growing season. Farmers have noted that the crop yield depends on the amount of ammonium nitrate that is applied during the period when okra is being harvested.

The principal winter crop is beans. Bean yields were rather low. Farmers attributed these low yields to the lack of certified seed for beans. The average yields and the range of yields obtained from farmers are given in Table 33.

The crops grown on the scheme are sold mostly on the uncontrolled market where prices are determined by supply and demand. Since Ngondoma farmers are able to plant summer maize as early as August because water is available, they have green maize for sale as early as November when the supply of green maize is limited and the price is high. When the supply of green maize becomes large and the price is low, Ngondoma farmers harvest their maize as grain. Based on their success with growing and selling early green maize, Ngondoma farmers also plant okra early. Early okra also brings a good price since Ngondoma farmers are among the first on the market with okra.

Initially, farmers were assured of a reasonable price for their commodities from two mines operating within 10 km of Ngondoma. Now, those mines are closed, and the Ngondoma farmers have had to seek other markets. The seasonal price for green maize and okra are presented below in Figure 14.



a. Green maize

b. Fresh okra

Figure 14. Price of green maize (a) and fresh okra (b) at Ngondoma.

The prices for green maize and okra are at their highest levels when Ngondoma farmers bring their first picking of green maize to market. As more supplies enter the market in late December and January, the prices drop sharply.

It seems fair to say that Ngondoma scheme is market-driven. After the nearby Commoner and Empress mines closed, the closest market was at Venice Mine, about 50 km away. Farmers have sought distant markets as local markets have shrunk. Some okra is marketed in Bulawayo, 300 km away. Private buyers also travel to the scheme to buy, especially okra and beans.

A major problem faced by farmers is their lack of cheap transportation. Farmers have to use ox carts to transport their products to a road where public transportation is available. Even when they reach public transportation, there is a limit to the amount they are permitted to carry on buses. Some farmers hire a vehicle to get their products to the main road or to distant markets.

Farmers also find it difficult to determine the prices they can expect to receive. Despite these difficulties, Ngondoma farmers operate their irrigation scheme so as to receive a high price for their products. If they began to harvest their crops 45 days later, gross margins would fall sharply, and the scheme might not be viable. The crop budgets for Ngondoma are presented in Tables 35-37.

The modal plot size is 0.6 ha. The gross margin for the modal plot is presented in Table 38. A gross margin of $3,423 for the modal plot shows why the farmers' irrigation committee is able to maintain the level of discipline necessary for the success of Ngondoma. Even a 0.3-ha plot would be capable of producing income in excess of the Universal Poverty Datum Line.

Farmers only hire labor during weeding and picking, when labor requirements are at their peak. In summer, hired laborers pick okra and weed maize. In winter, hired laborers weed and harvest beans.

2. Plot Size, Farmer Income, and Payment Capacity

The gross margins for plot sizes from 0.1 ha to 1.0 ha are presented in Figure 15. The UPDL of $1,680 and the 2UPDL level used by ARDA as an income objective are also indicated in Figure 15. The distance between the selected income objective line and the gross margin line indicates the payment capacity of the plot. For example, a plot of 0.29 ha could generate $1,680 in gross margins, but would have no payment capacity if the UPDL were the income objective. With the same income objective, a 0.4-ha plot would have a payment capacity of $602.

The Ngondoma scheme indicates that it would be feasible to meet a reasonable farmer income objective and a payment capacity high enough to pay for the sustained operation and maintenance of the scheme if strict cost control measures were imposed on O&M. One way to accomplish this objective would be to turn much of the O&M responsibility over to people with strong incentives to keep costs low and scheme performance high; i.e., the farmers on the scheme. This situation exists because of the interaction taking place among the market prices received for the high levels of production and an irrigation scheme which provides reliable, adequate water distributed in an equitable manner.

3. Value of Water

The gross margins generated on Ngondoma are high and the irrigation efficiency is fairly high at 40 percent (80 percent conveyance efficiency and an estimated 50 percent field efficiency). The gross diversion of water is 10,000 m^3/ha for maize and okra and 12,500 m^3/ha for beans. Therefore, the gross margin per 1,000 m^3 for summer crops is in excess of $400, and the gross margin for sugar beans is in excess of $200.

Table 35. Budget per hectare of early maize at Ngondoma.*

Input	Quantity	Cost ($)	Cost per Hectare ($)
Yield dry (t/ha)		0.9	
Field green (cobs)		26,000	
Price green (blend) ($)		0.18	
Price dry (grain) ($)		180.00	
Gross Income ($)		4,842.00	
Seed	25 kg	19.80/25 kg	19.80
Fertilizer			
Compound D	500 kg/ha	355.60/t	177.80
Ammonium nitrate	500 kg/ha	406/t	203.00
Pesticide			
Dipterex 2.5	4 kg/ha	0.90	3.60
Hired labor			36.00
Packing material	10 bags	2/bag	20.00
Transport			180.60
Total Variable Cost			640.80
Gross Margin			4,201.20

*In Zimbabwe dollars.

Table 36. Budget per hectare of sugar beans at Ngondoma.*

Input	Quantity	Cost ($)	Cost per Hectare ($)
Yield, dry (t/ha)		1.8	
Price ($/bag)		164	
Gross Income ($)		3,243.96	
Seed	60 kg		108.14
Fertilizer			
Compound C	200 kg/ha	467.80/t	93.56
Ammonium nitrate	100 kg/ha	406.00/t	40.60
Pesticide			
Carbaryl 85 WP	2.5 kg	15.25/kg	38.13
Packing material			39.56
Transport			120.10
Labor			139.00
Total Variable Cost			579.09
Gross Margin			2,664.87

*In Zimbabwe dollars.

Table 37. Budget per hectare of okra at Ngondoma.*

Input	Quantity	Cost ($)	Cost per Hectare ($)
Yield (bags)		100	
Price ($/bag)		50	
Gross Income ($)		5,000	
Seed	5 kg	4.50/kg	22.50
Fertilizer			
Compound D	400 kg	355.60/t	142.24
Ammonium nitrate	400 kg	406.00/t	162.40
Pesticide			
Dimethoate 40 EC	2.5 L	11/L	27.50
Thoidon 50 WP	2.5 L	12.40/L	31.00
Carbaryl 85 WP	1.5 kg	15.25/kg	22.88
Transport			348.48
Labor			132.60
Total Variable Costs			889.60
Gross Margin			4,110.40

*In Zimbabwe dollars.

Table 38. Gross margin of the modal .6-ha plot at Ngondoma.*

Crop	Area Planted (ha)	Gross Margin per Hectare ($)	Gross Margin per Plot ($)
Maize	0.4	4,201	1,680
Okra	0.1	4,110	411
Beans	0.5	2,665	1,332
Vegetables	0.2**		Subsistence
Total			3,423

*In Zimbabwe dollars.
**0.1 ha each in summer and winter seasons.

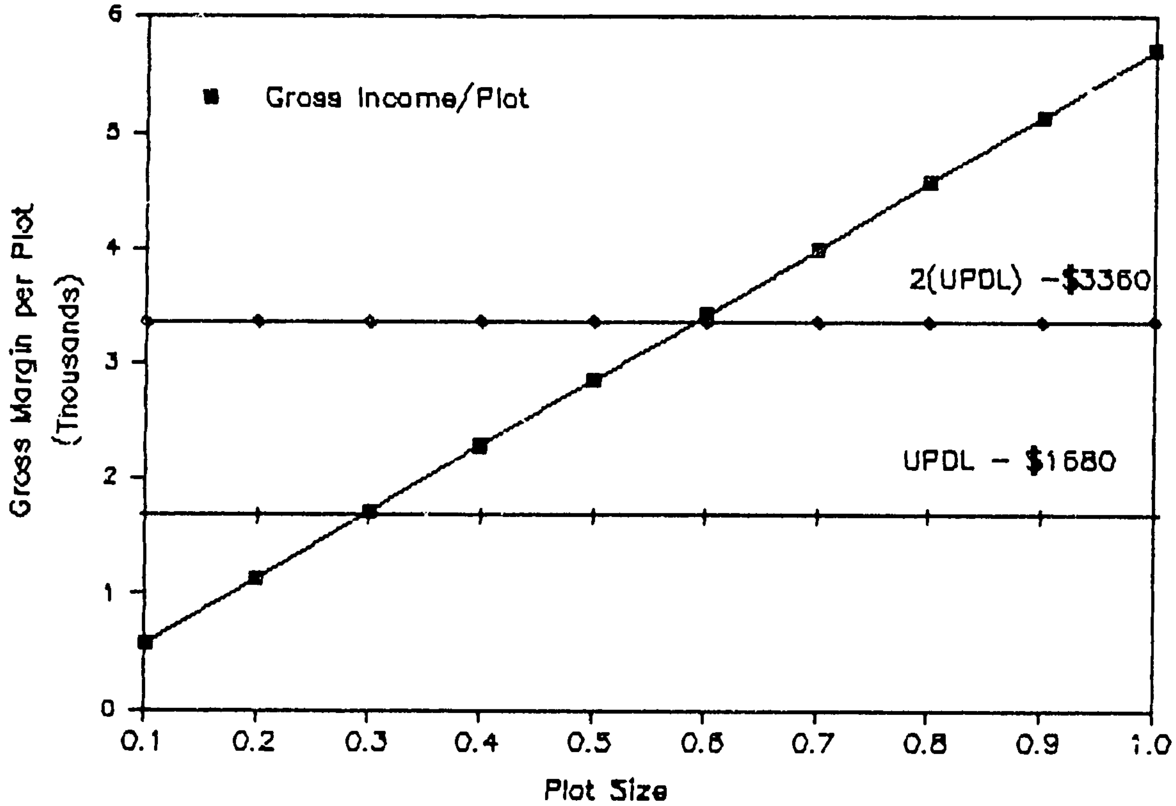


Figure 15. Plot size, income objectives, and payment capacity (Ngondoma).

There is additional water available for use, and there is the possibility of expanding into 16 additional hectares of land that were once part of the scheme. At first glance, it appears that such an expansion would be both financially and economically feasible.

4. Scheme Expansion: The Cost of Waiting

In the past, an additional 16 ha were irrigated at Ngondoma, but then the size of the scheme was cut back to provide additional water to the Empress Mine, which was then operating. The soils on the expansion area do not greatly differ from the soils on the area currently irrigated. It would appear reasonable to expect that the farmers on the expansion area could perform as well as those farmers on the area currently irrigated. However, if Ngondoma farmers depended entirely on local markets, the increased production from the 16 ha could depress market prices. However, with assertive marketing efforts, farmers should be able to continue to enjoy high early season prices for green maize and okra. Increases in irrigation efficiencies, particularly field efficiencies, could lessen the need for expensive capital investments.

The clear opportunity to expand Ngondoma suggests six issues that should be addressed:

1. If the expansion is economically and financially feasible, there is an opportunity cost in delaying the expansion.

2. It may be that the optimum size for expansion is less than the feasible 16.0 ha.

3. The possibility of substituting management for investment in physical structures needs to be considered.

4. The appropriate plot size must be determined if both income and payment capacity objectives are to be achieved.

5. The issue of who receives the plots on the expansion area must be resolved, including the issue of giving priority to existing plotholders.

6. Existing and new plotholders need to understand how their current marketing arrangements can be retained (at least) and perhaps expanded.

The incentive to deal with the last five issues can be enhanced by a clear understanding of the first -- the cost of waiting.

If is it assumed that the expansion will include the entire 16 ha, and current cropping practices will be repeated on the expansion area, the expected increase in farmer incomes and payment capacity is presented in Table 39. These data show that each year the expansion is delayed, the farmers on Ngondoma, and Zimbabwe, forego the opportunity to generate more than $100,000 of gross margins.

If UPDL ($1,680) is taken as the income objective, the resulting relationship between plot size and payment capacity is presented in Table 40. The payment capacity of the expansion increases as plot size increases since the "economic rent" generated by the expansion is shared among fewer farmers, leaving a larger residual that can be used for payment capacity. Note that if the plot size were to increase about 0.6 ha, hired labor costs would probably be greater than assumed in the crop budgets and yields might decrease somewhat.

No precise estimates were available of the costs to expand, but the general figures used in discussions seemed high relative to the work to be done. If after 1) the allocation of $1,680 for family income and 2) the payment of the O&M costs of $300/ha, a payment capacity of $32,736 remained, this would support an investment of $229,962 in the 16-ha expansion if the expansion had a 20-year life and if a 13 percent interest rate were used. An effective expansion should be able to be developed for less money.

Table 39. Gross margins foregone in Ngondoma each year due to no expansion.

Crops	Area (ha)	Gross Margin per Hectare ($)	Gross Margin for Expansion ($)
Summer			
Okra	3	4,110	12,330
Maize	12	4,201	50,412
Vegetables	1	subsistence	
Winter			
Beans	15	2,665	39,975
Vegetables	1	subsistence	
Total			102,717

Table 40. Payment capacity and plot size with $1,680 income allocation: Ngondoma expansion.

Gross Margin	Plot Size (ha)					
	0.3	0.4	0.5	0.6	0.8	1.0
	$					
Per plot	1,712	2,282	2,853	3,423	4,564	5,705
For 16-ha expansion	1,707	24,080	37,536	46,486	57,680	65,400

However, regardless of the economic feasibility of the expansion, it seems unlikely that sufficient funds will be available to finance an expansion of the nature currently anticipated. While every effort needs to be made to plan for an expansion that entails cost control (particularly capital cost control), alternatives should also be developed which are tailored to the level of funds which are likely to be available. For example, alternatives should be developed for an 8.0-ha expansion and for an expansion alternative that would be feasible with a limited, but specified capital budget. The cost of not considering such alternatives can be considerable. For example, an 8.0-ha expansion would be capable of generating gross margins of at least $25,000/year. If an 8.0-ha expansion were delayed four years, Zimbabwe and the farmers in Ngondoma would have foregone the opportunity to earn $100,000 in gross margins.

The level of capital investment required can depend partly on how the scheme is managed. It might be possible, for example, to use better water management to increase field irrigation efficiency. This, in conjunction with improvements in the existing storage reservoir and the conveyance system, could substitute for an additional storage reservoir.

Table 40 illustrates the importance of determining the combination of plot size and payment capacity that would be acceptable. Decisions must be made about plot size before the financial and economic feasibility of an alternative for investment can be determined. Every effort to control capital and O&M costs will be rewarded with the ability to settle more plotholders, while still maintaining an expansion which is feasible financially and economically.

The issue of who receives the new plots must also be determined. In particular, the eligibility of current plotholders for added area in the expansion is a central part of this issue. This issue also relates to the payment requirements imposed on plotholders in the existing and expansion area. If higher payment requirements are imposed on plotholders in the expansion area, plots in the expansion area will need to be larger than those in the existing area. The expansion raises many complexities, particularly in regard to equity, and these need to be worked out with the farmers before the expansion is undertaken.

As mentioned earlier, the Ngondoma scheme can be considered a market-driven scheme. The existing Ngondoma farmers are probably at least intuitively aware that expanding the scheme could affect prices received. If there were to be such an impact, it could probably be mitigated, if not eliminated, by developing a marketing strategy to accompany plans for scheme expansion.

5. Conclusion

Ngondoma scheme is highly productive and highly profitable. It demonstrates that irrigated agriculture, not just irrigation, is the key to economic and financial feasibility. Intensive agriculture is made possible at Ngondoma by the existence of an adequate, reliable, and equitably distributed supply of irrigation water and by a group of farmers who have a history of producing crops early to obtain high market prices.

G. SYSTEM STRENGTHS AND WEAKNESSES

1. Strengths

Productivity. Ngondoma scheme is highly productive and profitable due to good soil, adequate water supply, and good management.

Organizations. There seems to be cooperation among all three groups represented on the scheme (IMC, AGRITEX, and the farmers). The IMC is well organized with written by-laws that guide the operation of the scheme.

Extension and Input Use. The extension service is good, effective, and highly regarded by the farmers. Farmers seem to readily accept extension recommendations for input use.

Cropping Pattern. The cropping schedule is geared towards getting into the markets first, thus realizing higher returns.

Scheme Size. The scheme is small enough to be very manageable and seems ideal for farmer management.

Water Supply. There is an adequate and reliable water supply from Ngondoma Dam, with more than sufficient water for the proposed 16-ha expansion.

System Efficiency. The canals are lined and seem to be well maintained. Conveyance and distribution efficiencies were as high as 80 percent and 93 percent, respectively.

Soils. The soils are well suited for sustained irrigation (including the soils in the proposed expansion area).

Irrigation Schedule. There seems to be a formal irrigation schedule, and there is mutual cooperation among irrigators.

2. Weaknesses

Bureaucracy. The government bureaucracy seems rigid, which is crippling further development of the scheme. Decision-making is delayed and ineffective.

Farmers and AGRITEX. Farmers seem to lack the initiative to develop the proposed area for irrigation because they fear that if they try new approaches on their own and fail, the government will be angry.

Transport. Physical access to market is limited by lack of transport.

Records. There are no records of soil analysis and yields on which to base decisions about current input use.

Cost of Delay. The cost of delay in implementing the proposed expansion is significant.

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VII. GLOSSARY OF ABBREVIATIONS

AFC	Agricultural Finance Corporation
AGRITEX	Agricultural extension service
ARDA	Agricultural and Rural Development Authority
AWC	Available water capacity
C	centigrade
cm	centimeter
CMB	Cotton Marketing Board
DRSS	Department of Research and Specialist Services
dS	deci Siemens
GMB	Grain Marketing Board
GOZ	Government of Zimbabwe
h	hour
ha	hectare
Hp	Horsepower
IMC	irrigation management committee
JFW	Joint Field Workshop
Kcumec	thousand cubic meters
kg	kilogram
km	kilometer
kW	kilowatt
L	liter
m	meter
MEWRD	Ministry of Energy and Water Resources Development
mm	millimeter

O&M	operation and maintenance
rpm	revolutions per minute
s	second
t	ton
UPDL	Universal Poverty Datum Line
WUA	water users association
ZESA	Zimbabwe Electricity Supply Authority

VIII. APPENDICES

APPENDIX A

ANALYSIS OF SMALL-SCALE IRRIGATION SCHEMES IN AFRICA: DEVURE IRRIGATION SCHEME, ZIMBABWE

Prepared by

Max Donkor

This study received support from the
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EXECUTIVE SUMMARY

INTRODUCTION

Small-scale irrigation projects provide a foundation for rural development and growth by providing employment, income, and food security. This activity was an extension of the Zimbabwe Joint Field Workshop (JFW) funded by the United States Agency for International Development. The Joint Field Workshop investigated a range of small-scale irrigation schemes. Preliminary findings on the Devure irrigation scheme are reported here. The physical system and water management aspects of the irrigation project are emphasized since the activity was a disciplinary one to obtain water management data over a longer period than was possible during the Joint Field Workshop.

This activity was funded by USAID through the Water Management Synthesis II Project of Colorado State University. Additional funding was provided by the American Water Foundation in the form of a research grant to the author. The study was executed with the cooperation of AGRITEX and the University of Zimbabwe, both of which provided equipment and personnel when available.

OBJECTIVES

The broad objectives of the activity were the following:

1. Provide additional and more detailed input for the evaluation of small-scale irrigation in Zimbabwe.

2. Provide field data for the doctoral thesis of the author, which had the following objectives.

   - Develop an irrigation management model based on observation-response practices.

   - Incorporate the "how" aspect into scheduling irrigation.

   - Determine the economic feasibility of different water allocation strategies based on this approach.

   - Test the model on an actual small-scale scheme in Zimbabwe (Devure scheme).

EXECUTION OF ACTIVITY AND TIMETABLE

This activity was intended to be a case study of an irrigation scheme using the interdisciplinary approach applied in the Joint Field Workshop. The difference was that it was to take place over the whole winter growing season (May-October). However, due to a number of factors, including financial constraints and administrative problems, the activity began in June and ended in mid-September, 1987. Despite drawbacks, it was possible to collect useful and detailed irrigation management data (which are still being analyzed). The timetable for the activity is in Annex A.

SITE DESCRIPTION

The Devure irrigation scheme is a small-scale scheme managed by AGRITEX in the province of Manicaland. Devure scheme was started in 1946 with 40 ha and 30 plotholders. At present it covers 271 ha and has 321 plotholders. Plot sizes range from 0.2 to 1.6 ha and the modal plot size is 0.4 ha.

The scheme layout is unusual since the cultivated areas are scattered. This was probably done to take into consideration the suitability of the land for irrigation (Annex B). The source of water supply is the Devure River. Water is diverted by an overflow weir about 7 km upstream on the river. The flow is then conveyed by gravity to the project. The project area lies just northwest of the confluence of the Devure and Save Rivers. Excess water is disposed into both rivers depending on the block of origin.

Two general soil types occur over the project area which are of alluvial and colluvial origin. The alluvial soils are loamy sands and sandy clay loams and are the most prevalent. The colluvial soils are mainly dark brown sands. In terms of land suitability for irrigation, all the soils have restrictions of varying degrees due to texture, soil depth, or excessive perviousness. However, with adequate water supply, reasonable crop yields are obtained.

The total length of the main canal is about 13 km. Part of the canal is lined, but overall losses in the main canal are considerable. The scheme has an AGRITEX-appointed irrigation manager and a staff consisting of five extension workers and a maintenance gang. The staff provide extension advice and support in cropping, water management, and credit. The effectiveness of the extension staff differed among the blocks. Generally, the extension staff was very effective in blocks A and C, which were technically superior in the sense that their design layouts were more regular and canals were lined.

Within the project, the degree of effectiveness of water management in terms of adequacy, reliability, and equity varied. These variations depended on factors such as location of the block, location of the field within the block, the technical state of the infrastructure within the block, and the effectiveness of the extension officer or water bailiff.

At the source, the Devure River flow is adequate to satisfy the water rights of the scheme and reliable due to the existence of the Ruti Dam upstream. This was confirmed in that Devure was the only irrigation project to have no water supply problems during the winter (dry season) of 1987. Both the neighboring Nyanyadzi and Mutema (gravity section) schemes had inadequate or no water supplies.

The method of irrigating the fields also differed among blocks. The "oblong basin" method was used on the blocks which had unlined canals and little infrastructure (i.e., Block B). This method was a form of wild flooding, involving a lot of improvisation and labor. A more controlled method using eight siphons to deliver approximately 16 L/s was used in blocks A and C. One tentative observation is that cooperation between farmers and extension staff, and administrative efficiency (i.e., scheduling of delivery) seems to be better in blocks A and C.

The crops grown during the season under study were wheat, tomatoes, and beans. The best profit margins, using a five-year farmer survey, were obtained from the tomato crop. Most inputs are provided by a local canning company, LEMCO, as part of a purchasing contract with the farmers. The wheat is sold to the local Grain Marketing Board depot.

FINDINGS AND CONCLUSIONS

Some of the preliminary findings based on the data collected are summarized below.

Joint Field Workshop

As a follow-up to the Joint Field Workshop, this activity was successful in the following ways.

1. The interdisciplinary approach advocated by the workshop was informally tested. Local team members voluntarily contributed to data collection in cooperation with the author.

2. More detailed data on the technical aspects of a small-scheme over a season are now available.

Scheme Objective

The objectives of most schemes were difficult to establish during the Joint Field Workshop. However, this activity provided the opportunity to look at a project in depth. Access to "old" reports enabled the author to piece together the objectives of the project since its construction in 1946. It is recommended that in future "rapid appraisal" joint field workshops, a specific period be scheduled before the activity to assemble current and historical project information.

Site Evaluation

From scheme records, soil variability was initially considered when the project started (i.e., Block A, 1946). However, it did not appear that later developments took adequate account of the soils.

Future rehabilitation, especially if done incrementally, should account for differing soil characteristics in order to choose the most effective step available at a given time. For example, if there were not enough resources to line all canals of the project, the resources could be used to line the parts of canals that have the most significant effect on water adequacy, reliability, or equity.

Water Management

Improved water management and allocation practices are required in the project as a whole. An indicator of this is the amount of water which drains into the Save and Devure Rivers from the scheme.

Improvements can be classified into three categories: infrastructural management improvements, farmer-oriented field water management improvements, and administrative improvements.

Infrastructural Management Improvements. This would include improving the methods for diverting water to fields (i.e., using siphons instead of bank cuts), improving uniformity through land leveling, and reducing water loss rates through canal improvements (i.e., lining). In blocks B and D, infrastructural management improvements are required before the others described above can be effective.

Farmer-oriented field water management improvements. These improvements require little or no infrastructural changes and include irrigation times and schedules, timing of change-overs to reduce administrative losses, and basic understanding of the flow process on an irrigation field. Knowledge of these improvements can be extended to large groups by the extension staff if suitable audio-visual materials can be developed.

The major objective of farmer-oriented water management improvements would be to change the farmers' conception of adequacy or inadequacy of their water supply, and to impress upon them how their routine irrigation activities affect other farmers and the project as a whole.

At Devure, since using watches involves excessive cost to farmers, substitute indicators for time of irrigation can be found (e.g., advance distance down the field).

Administrative Improvements. "Administrative" refers to the actual organization of water allocation down to the field level, including gate operation, recordkeeping, and analysis. The lack of control over delivery time to a farmer and the relative inflexibility of the sequential rotation system lead to considerable operational losses in the canals. Even setting up a traditional time-based delivery and irrigation schedule on paper would require a controlling source (i.e., water bailiff) to keep track of it. This type of improvement would therefore involve training and motivation sessions that explain the need for control and flexibility. If water bailiffs can be convinced of the effect on the system as a whole, traditional social pressure can be brought to bear on non-cooperative farmers.

General Conclusions

Some general conclusions and observations resulting from this activity are the following:

1. The network resulting from the Joint Field Workshop proved very valuable in completing this activity.

2. Planning for research activities that follow joint field workshops should be more detailed.

3. Detailed seasonal data for a small-scale irrigation project in Zimbabwe is now available.

Further, the following specific technical conclusions can be made about the Devure irrigation scheme:

1. It serves as a vital source of food, employment, and economic development for a wide area.

2. It has a very reliable and adequate source for water supply.

3. Certain blocks (B and C) need rehabilitation to improve production.

4. Irrigation management needs improvement, especially in delivery scheduling and on-farm water management. Losses in conveyance and distribution canals are high, and improvements in water management would save a significant amount of water. These savings could be used to expand the project area and provide plots for farmers on a long waiting list (about 500).

5. Farmer participation in the management of the project should be encouraged. This would facilitate early divestment of AGRITEX control of the project.

I. INTRODUCTION

Devure irrigation scheme (Figure 1) is one of the small-scale AGRITEX schemes in the Manicaland Province. It is located on the southwestern corner of the Buhera Region, to which it administratively belongs.

Devure was started in 1946 with 30 plotholders cultivating 48 ha. The original section of the scheme now forms part of Block A. Currently there are four blocks (A, B, C, and D), with Block B divided into BI, BII, and BIII and Block D divided in DI and DII. The current size of the scheme is 271.2 ha with 321 plotholders.

The scheme lies just upstream of the confluence of the Save River and its tributary, the Devure River. Birchenough Bridge is the major landmark for the scheme, and the Birchenough Bridge Growth Point serves as the commercial and administrative center for the scheme. The scheme straddles both sides (north and south) of the main highway from Mutare to Masvingo. Most plotholders live close to their plots, especially those who have plots in Block A. They live in the original village, Chinyamatikiti, which is about 4 km from the Masvingo road. There are some plotholders, however, who still live on their original dry land plots, which are scattered over the surrounding area within about 8 km of the Birchenough Bridge Growth Point.

The scheme is under the overall charge of an AGRITEX-appointed irrigation manager. An organizational chart of the scheme is shown in Figure 2.

Devure is a gravity scheme, except in Block DII where canal flow is collected in a sump and pumped into sprinkler lines. Devure scheme is located in agro-ecological region 5, with low and erratic rainfall totaling about 400 mm annually and very high evapotranspiration (2080 mm). Agro-ecological region 5 is generally suited for extensive livestock production.

The soils of the scheme are mainly siallitic alluvium from sandstone and quartzite. However, some parts of Blocks A and C have soils derived from fersiallitic colluvium from granite (GOZ, 1985). The alluvial soils are sandy loam and loamy sands or sandy clay loam, while the colluvial soils are mainly dark brown sands or yellow-brown sandy clay loam.

Based on land suitability for irrigation, the block classification is illustrated in Table 1.

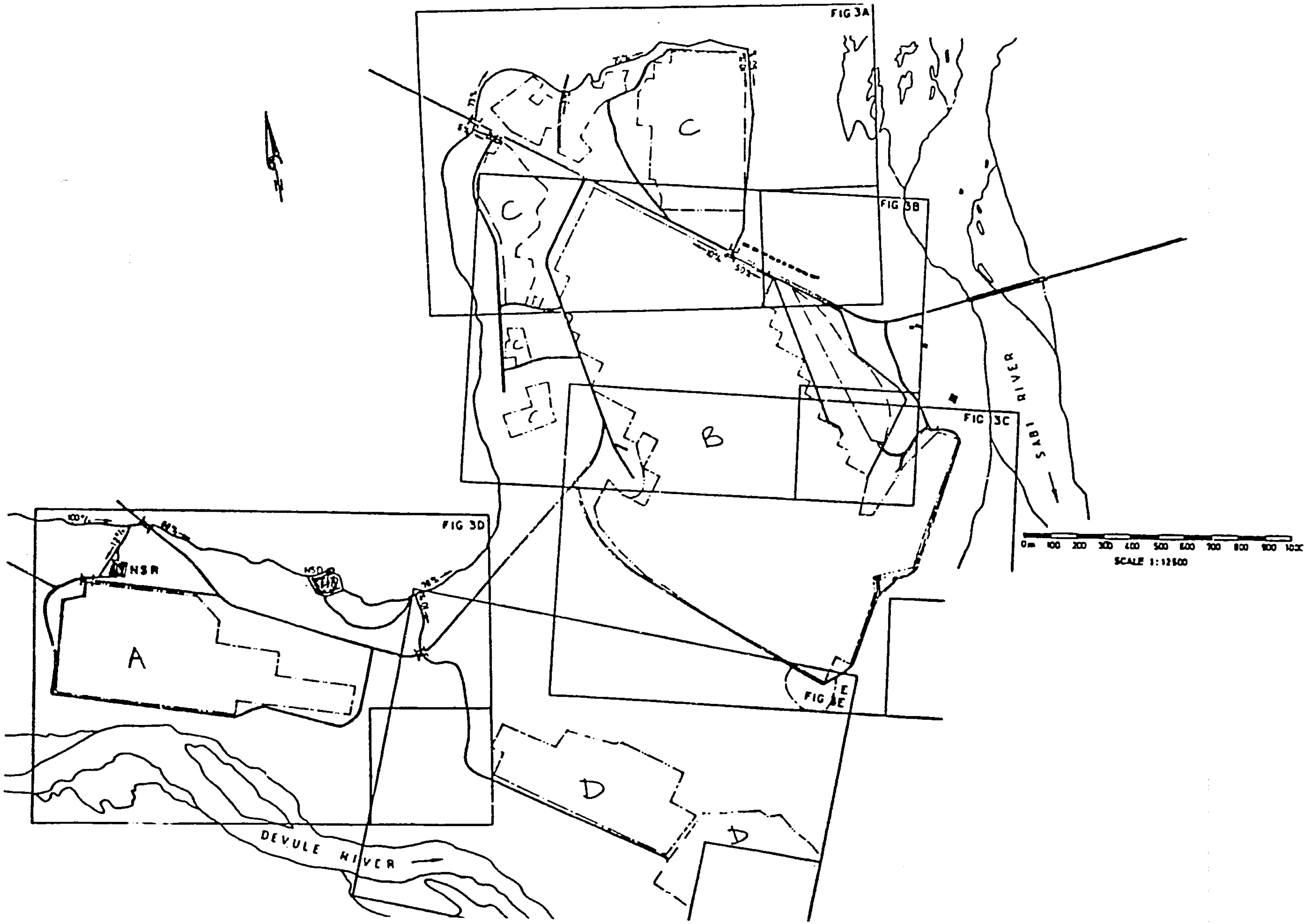


Figure 1. Layout of Devure scheme (Source: GOZ, 1985).

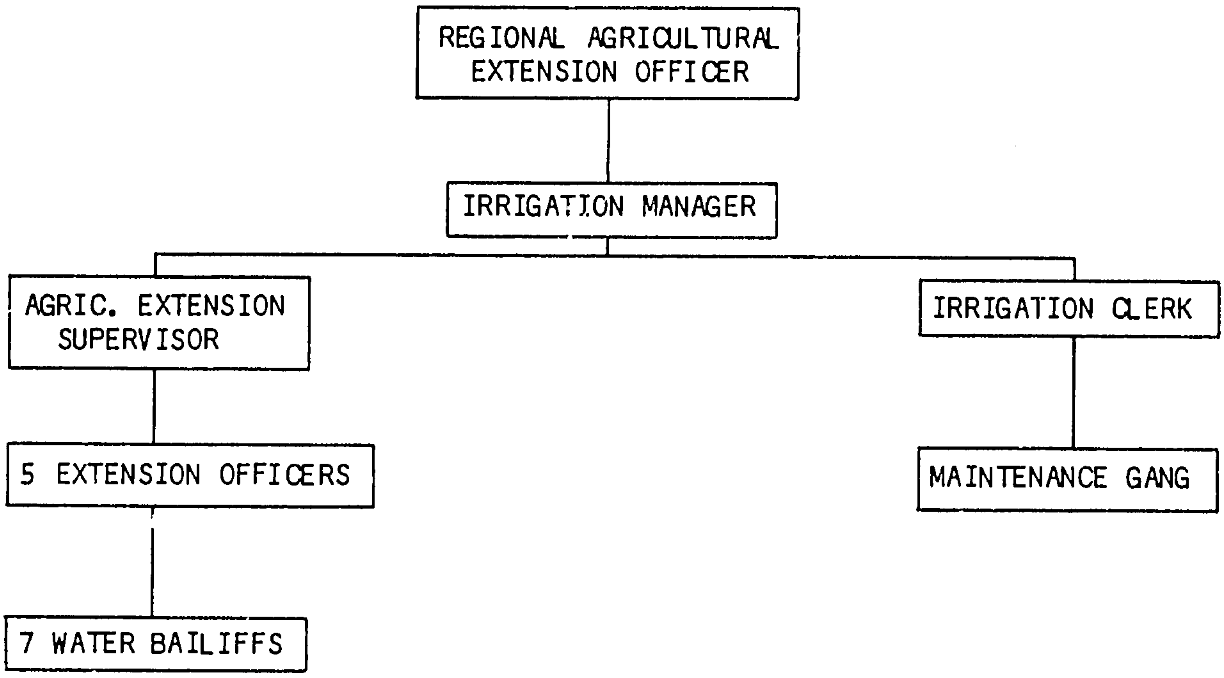


Figure 2. Organizational chart for Devure scheme.

Table 1. Land suitability for irrigation.

Block	Land Class*	Percent
A	S	20
	B	80
B	S	90
	B	10
C	B	45
	C	10
	S	45
D	S	60
	B	40

*Class B: Suitable for irrigation with moderate soil limitations (soil texture).
Class C: Very restricted suitability, severe limitations (soil depth).
Class S: Very restricted suitability (excessively pervious sands).

The original objective of the scheme was difficult to determine due to the lack of documentation. After living there, and in discussions with the older farmers, the most logical objective, given the socio-political conditions prevailing in 1946, appears to have been food security. This is because the extreme dryness of the area results in normal dryland yields only once in 5-6 years on average. From scheme records, it was established that until 1976 the scheme served to deliver supplementary irrigation for summer cropping.

The current objectives of the scheme are as follows:

1. To serve as a source of grain for the surrounding area, which crosses regional boundaries to the Bikita, Chipinge, and Mutare regions.

2. To create employment and income for the inhabitants of the area. By observing economic conditions for four months it became apparent that the scheme was one of two major sources of economic activity for a very wide area surrounding the Birchenough Bridge Growth Point. The other major source of income was the Army Camp about 2 km to the southeast.

II. THE PHYSICAL SYSTEM

A. HYDROLOGY

The only source of water to Devure scheme is the Devure River. Until 1976, the scheme was only a summer supplementary scheme since the river dried up regularly around August-September. Since the completion of the Ruti Dam upstream on the Devure River, however, enough water has been available year-round to ensure a winter crop and early planting of the summer crop.

The water right (No. 1499) was obtained for the scheme in 1958. It permits the abstraction of 0.07788 m^3/s) per 100 ha to a maximum of 404.7 ha. Examples of Devure River discharge patterns before and after the construction of the Ruti Dam are illustrated in Annex C and Figure 3. The dam has removed the uncertainty associated with periods of no flow because it has guaranteed the reliability of water supply to the scheme.

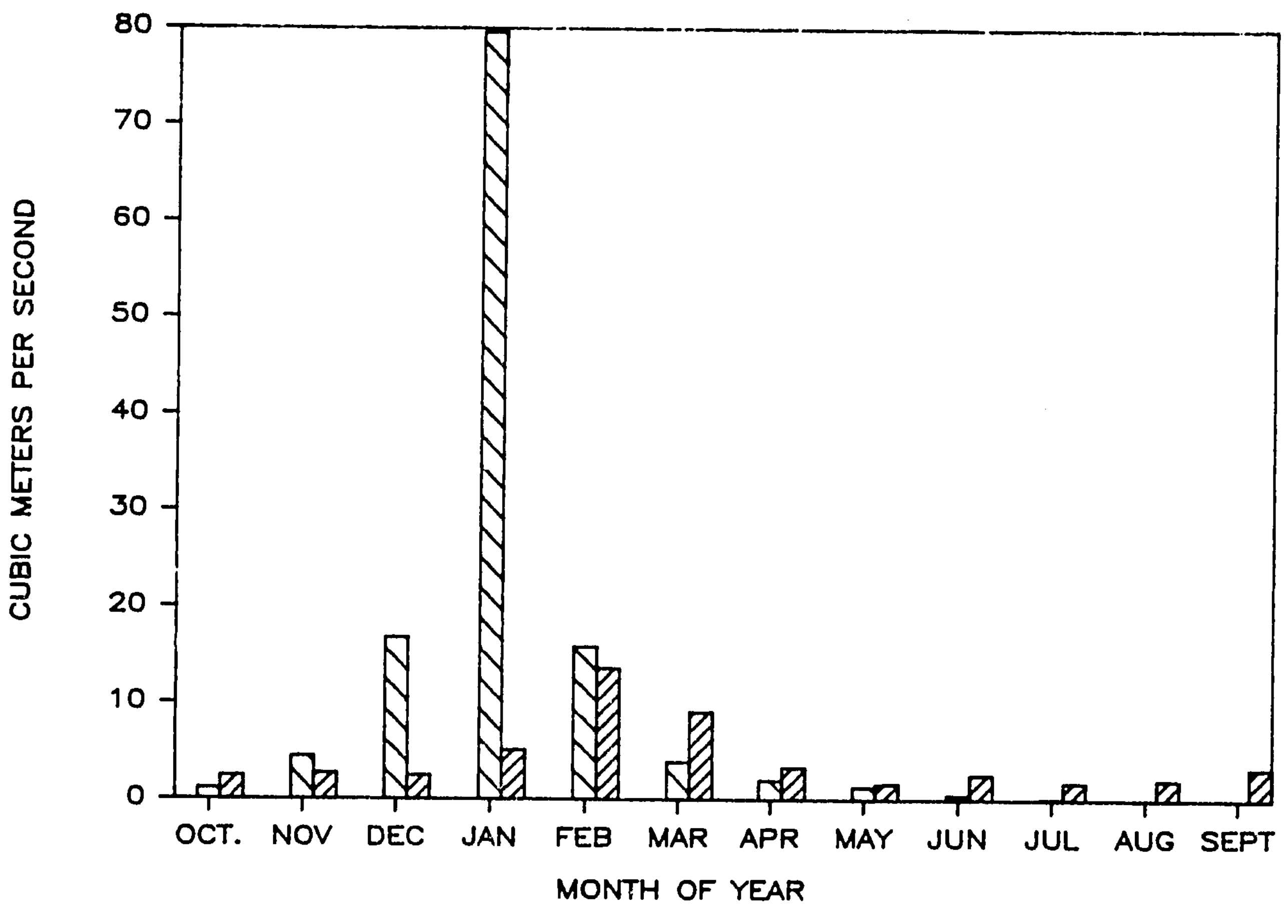


Figure 3. Discharge from Devure River before and after the Ruti Dam was constructed (Devure).

Water for the scheme is diverted by an overflow weir constructed across the Devure River and conveyed 6-10 km to the various blocks (Figure 4). The diversion weir was broken on the west side and its capacity has been significantly reduced by siltation upstream. To quote an extension worker's report on the Devure irrigation scheme field day on 24 January 1986:

> "The weir is at present 100 percent silted. Because of this siltation, the water is always not enough throughout the year. A and DI Blocks are the only areas with lined in-field canals. The rest are not lined and this is also contributing to the shortage of water due to evaporation and seepage."

Parts of this quote are exaggerated, but it reflects the frustration with maintenance of the weir. The weir is under the charge of the Ministry of Energy and Water Resources Development (MEWRD), and although maintenance of the weir is a high priority for the Devure irrigation scheme management and farmers, MEWRD seems to have given it a low priority. This view is supported by records of the scheme which show that the weir has been broken since the mid-1970s.

The only measuring structures between the diversion weir and the nearest block on the project, Block A, are a gate-spillway about 600 m downstream of the weir and a cutthroat flume, about 5 m upstream of the Block A inlet. The gate is rusted and needs replacement, but the flume operates reasonably well.

B. SOILS

As mentioned in the introduction, the soils of the scheme are either siallitic alluvium (sandstone and quartzite) or fersiallitic colluvium (granite). A more detailed illustration of the soils in the scheme is presented in Figure 5. Large parts of the scheme (i.e., areas with 4UM2 soils) have very restricted capability for irrigated land use due to excessively pervious sands. Using double-ring infiltrometer experiments, the infiltration characteristics of the soil types in Devure scheme were measured (Table 2).

Table 2. Kostiakov infiltration functions for soil types at Devure scheme.

Soil Type	Kostiakov Infiltration Function*
A) 4UM3	Z = 0.010 t^0.552
	Z = 0.694 t^0.514
B) 4UM2	Z = 0.38 t^0.74
	Z = 0.741 t^0.563
	Z = 6.334 t^0.353
C) 5CG2	Z = 0.224 t^0.889

*Units: Z = cm and t = minutes.

Figure 4. Devure scheme showing main canal (Source: GOZ, 1985).

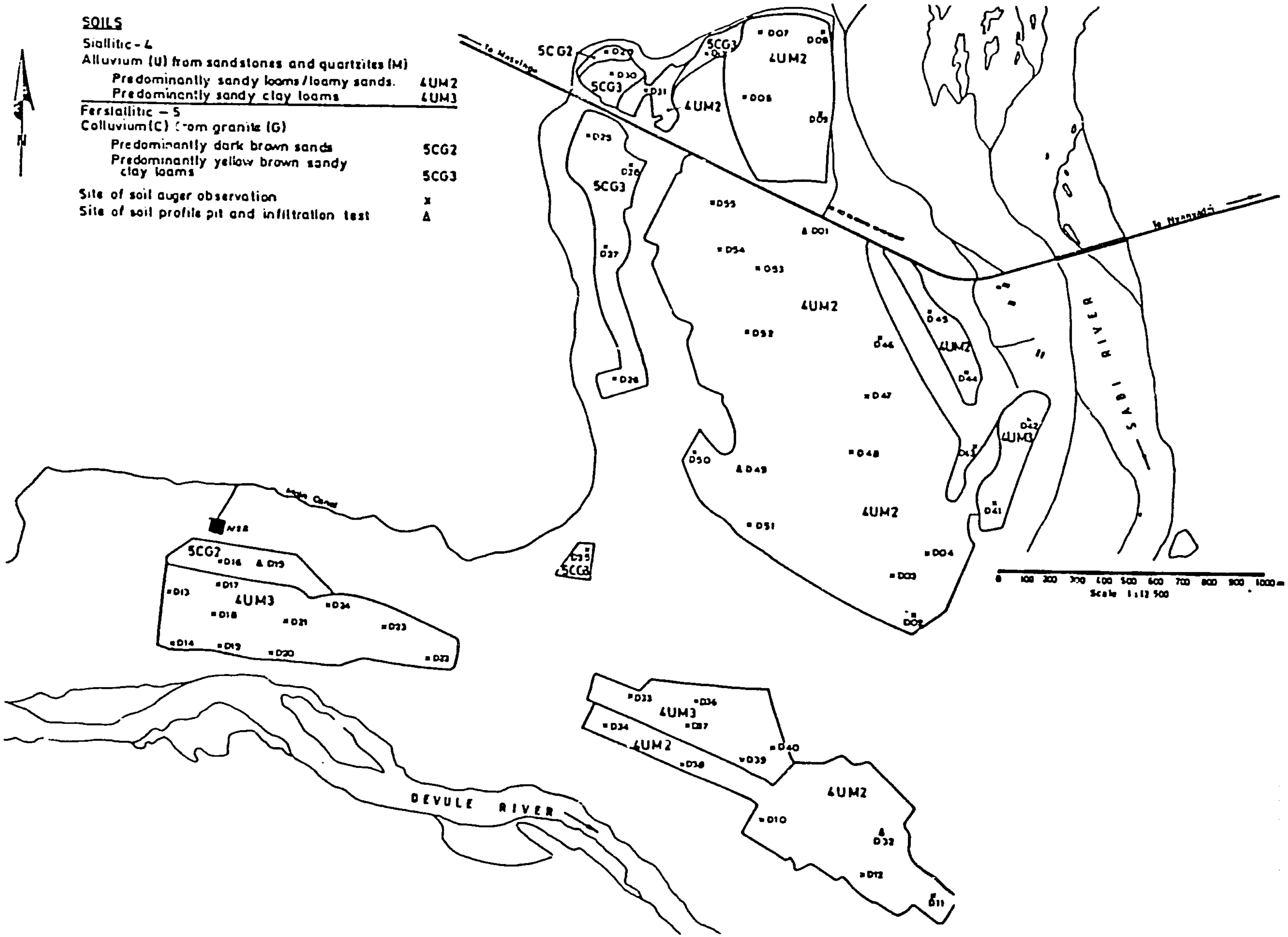


Figure 5. Soils on Devure scheme (Source: GOZ, 1985).

Under the Zimbabwean Soil Classification System, the siallitic soil types can be classified as Save U2. This soil series has the following approximate properties (Meterlerkamp, 1975):

a) pH = 7.3-7.6

b) Available Water Content (AWC) = 10%

c) Moderate infiltration rates

d) Moderate fertility status

e) High base saturation and cation exchange capacity

In terms of productivity, the soils of alluvial origin are most probably the best suited for sustained irrigation without special management problems. The more sandy areas, under irrigation, will require frequent, low amounts of water application to improve irrigation efficiencies.

C. LAYOUT AND STRUCTURES

The different blocks of the scheme are scattered over a triangular area formed by the confluence of the Devure and Save rivers (Figure 4). All the blocks except DII are gravity-irrigated. Water diverted from the Devure River is conveyed approximately 6.5 km before reaching the first intake at Block A. In total, the main canal takes "a long and winding road," crossing the main Mutare-Masvingo road twice before discharging excess flow into the Save River. Its total length is approximately 13.5 km.

The initial 7.5 km of the main canal is unlined. The first 600 m is cut through rock to the main inlet gate, which is in disrepair and rotted. The next section is an unlined, grassed waterway to the take-off to Block D. There are only a few control structures in this section of the main canal.

Apart from the rusted main inlet (and spillway to Devure), the next major structure is a large inverted siphon built in 1953. The siphon was probably built to compensate for a landslide which washed away a section of the canal about 2 km from the diversion. The only other structures that exist in this section are a few culverts, the cutthroat flume just upstream of the intake to Block A, and a non-functional night storage dam.

The remaining section of the main canal (downstream of the off-take to Block D) is cement-lined. According to the project management, this was done in the post-independence period to control heavy canal losses due to the sandy soils. A review of the farmer survey and discussions with farmers in Block B and C led to the conclusion that the lining of the main canal has significantly improved the reliability and adequacy of flow to both blocks. The lining is generally well-maintained and seepage losses along this section are relatively low.

Canals within blocks vary in size, slope, and whether they are lined or not. The number and quality of water control structures also varies. Blocks A and D have lined canals up to the field edge and an adequate number of well functioning rectangular gates for water control. In Block A, side (or long) weirs are used to maintain water levels in the canals and at discharge points in the main drain. These canals are trapezoidal in shape.

In Block B, distributary canals are either partially lined or unlined. They have a rectangular shape if lined and a parabolic shape if unlined. All farm canals are unlined and irregular in shape. There were only a few gates for water control, which were poorly maintained. Water control is achieved through improvisation, such as filling a canal with rocks to divert flow or cutting the banks of a distributary or farm canal to supply water.

At the field level, water is applied to border strips 3-4 m wide and 40-100 m long. Siphons are used to apply water in Block A and the gravity section of Block D. In Block B, water is diverted to field ditches and released to the fields using bank cuts. The distribution system in Block B is in very poor condition and seepage losses are high. In Block A, the leakages that occur are mainly attributable to leaks in the joints of the lining and cracks in the canal walls.

The sprinkler system in Block DII was not in operation, but from observation of the lines, it is in a poor state of maintenance. The design has a sump in which canal water is collected and then pumped into the sprinkler lines using a diesel-driven, axial-flow pump.

Problems occur at the tail ends of the distributary canals in Block B since the available head is inadequate. This results in long irrigation times and sometimes no flow.

D. RESOURCE CONSERVATION

Severe soil erosion was evident in the areas adjacent to the irrigation blocks. A section of the village of Chinyamatikiti, adjacent to the Devure River, has very large gullies which will threaten the foundations of some of the houses in the future.

From observation, erosion is mainly caused by a combination of overgrazing and considerable wind velocity, especially during the dry season. These conditions predispose the soil to gully formation at the onset of the rains, which are heavy and of short duration.

A program of soil conservation both within and around the project can forestall long-term damage. This problem is not local, but occurs along the entire Save River catchment. An interdisciplinary and interministerial effort would be required to develop an incremental, large-scale, conservation program in the Save Valley.

III. CHARACTERISTICS OF SYSTEM MANAGEMENT

A. WATER SUPPLY, ALLOCATION AND DISTRIBUTION

Water is diverted from the Devure River about 7 km upstream from Block A using an overflow weir. The flow ranges from 600 L/s to 700 L/s at the diversion point. In the unlined part of the main canal (approximately 8 km), an average of 40 percent of the flow is lost, mainly through seepage. The loss rate ranges from 1.5-5.1 L/s for each 100 m. At the only measuring structure in the project area (cutthroat flume at Block A), the total daily discharges ranged between 300 L/s to 420 L/s over a period of 4 years. An approximate percentage distribution of this flow between the blocks is shown in Figure 6. Other reasons for water loss along the main canal are the following:

1. Abstraction of water by livestock (about 3,000 cattle graze along the main canal).
2. Controlled spillage at culverts.
3. Lack of canal bank maintenance, leading to periodic breaks in the embankment.

Due to the variability in the soil characteristics, a detailed soil survey along the main canal may reveal sections where benefits from lining may more than justify the costs. This selective approach to lining the canal may be a feasible alternative to doing nothing or to completely lining the remaining 8.5 km of the canal.

AGRITEX water bailiffs control water allocation from the intake gates to each block. Ideally, water allocation is supposed to follow the following guidelines.

1. Water is to be delivered sequentially along distributary canals and farm canals.
2. Deliveries begin at 6:00 a.m. and end around 6:00 p.m. Night irrigation is allowed during peak periods.
3. An irrigation interval of 8-10 days (fixed interval, fixed amount delivery schedule) is envisaged by the management and the farmers.
4. Bailiffs keep a daily record of farmers who have access to water on a particular day.
5. Within a "command area" (area served by a distribution canal), control is in the hands of farmers. This means as one farmer finishes irrigating his plot, he passes the delivery to the next farmer downstream.

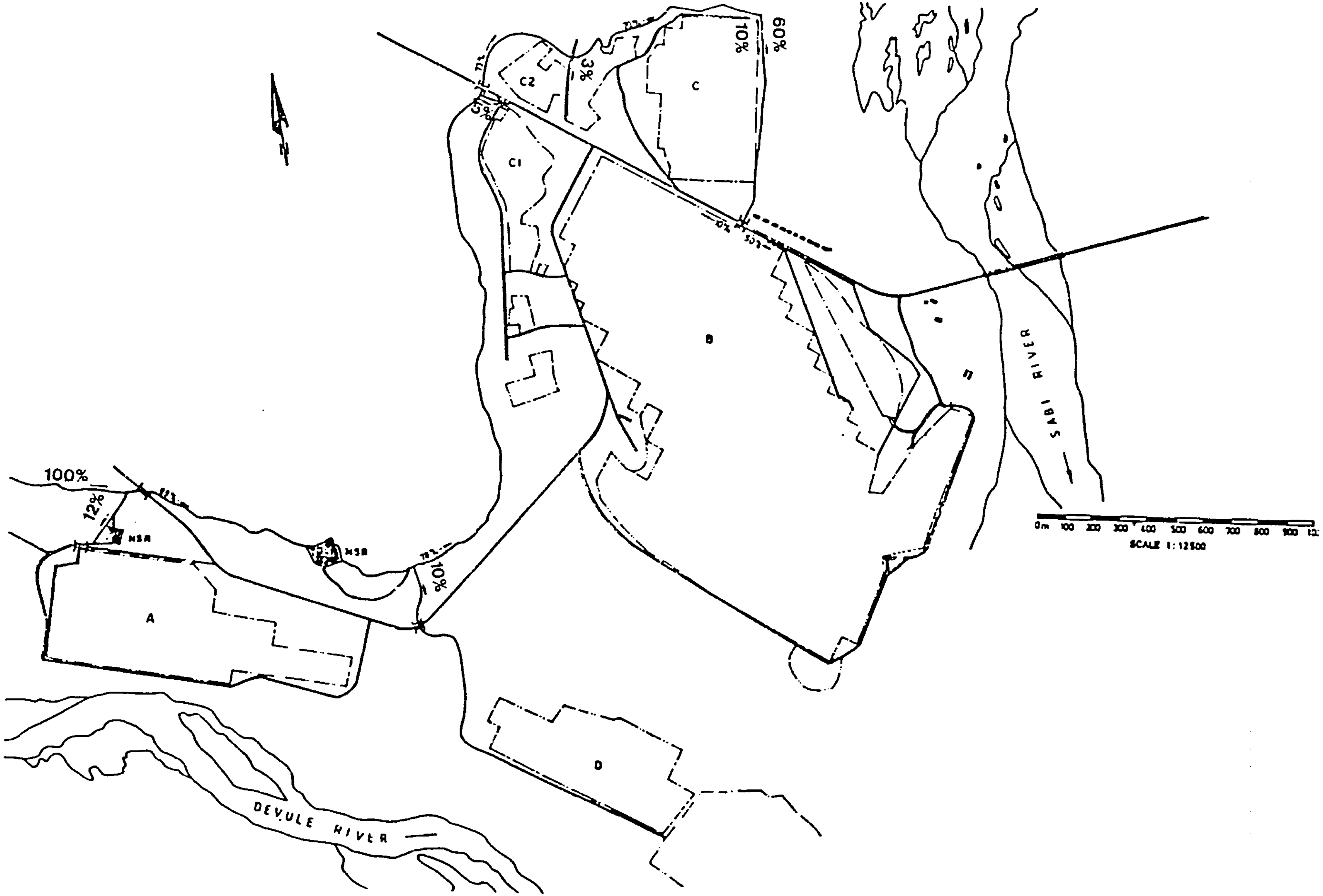


Figure 6. Percentage of flow distribution between blocks, Devure scheme (Source: GOZ, 1985).

These guidelines describe how water is to be allocated on the project. It does not represent an irrigation schedule in the traditional sense since there are no guidelines for the duration of irrigation.

Some changes instituted during the study were:

1. An addition to the daily record of farmers who irrigate on a particular day: the beginning and end times of water access by a farmer were observed and recorded.

2. The daily records over the whole season were to be analyzed to determine water adequacy and reliability. Also, the delivery time to a farmer was to be compared with the actual time needed per field; and the amount of discharge wasted as an operational loss was to be obtained.

Some aspects of water management which were analyzed from field data were the following:

1. The effect of location of plot (head (H), middle (M) or tail (T)) on the number of delivery turns during the season.

2. For each location (H, M, or T), the variation of the irrigation interval over the season.

3. For each irrigation event (1st, 2nd, or 3rd), the effect of plot location (H, M, or T) on the mean irrigation interval.

4. The relation between plot size and the mean standard deviation of duration of deliveries and mean duration of deliveries per unit area.

The relation between plot location and the number of irrigation turns observed is shown in Figure 7. The number of turns decreased from the head to the tail sections. This may be due to a combination of easier access and a perception of reliability. Since the allocation process is based on sequential rotation, the cause of the differences in the number of irrigation turns must be due to skipping turns.

Figures 8, 9, and 10 show the variation of the maximum, mean and minimum between irrigation events for locations at the head, middle, and tail sections, respectively. Generally, the irrigation intervals increased from the head sections to the tail sections. For example, the maximum interval between the 1st and 2nd irrigation events varied from 24 to 29 days from head to tail.

In addition, there was a decrease in the maximum intervals over the season and an increase in mean intervals between the 2nd and 3rd irrigation events at all locations. This latter observation can be partially explained by the peaking of Block A water demand during this period. Further, note that the planned interval of 8 to 10 days is seldom achieved.

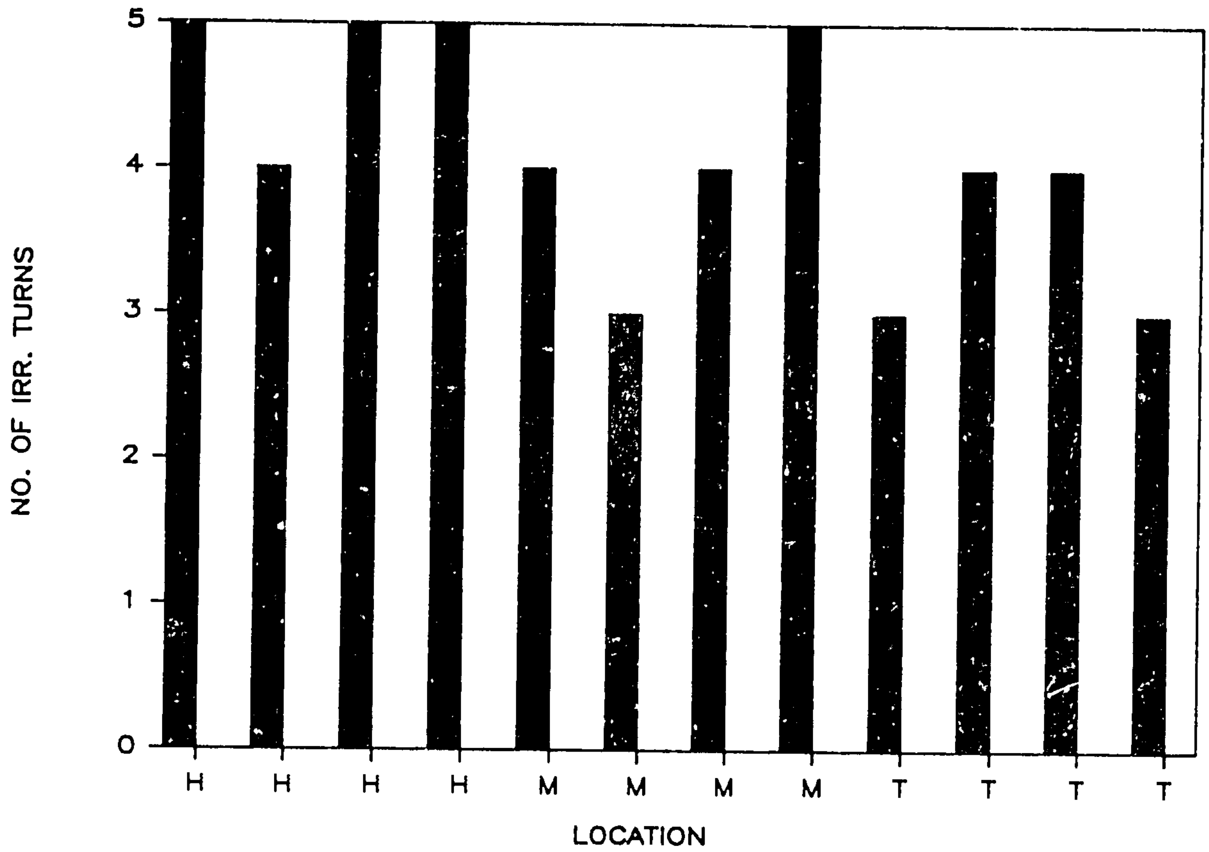


Figure 7. Effect of plot location on number of irrigation turns.

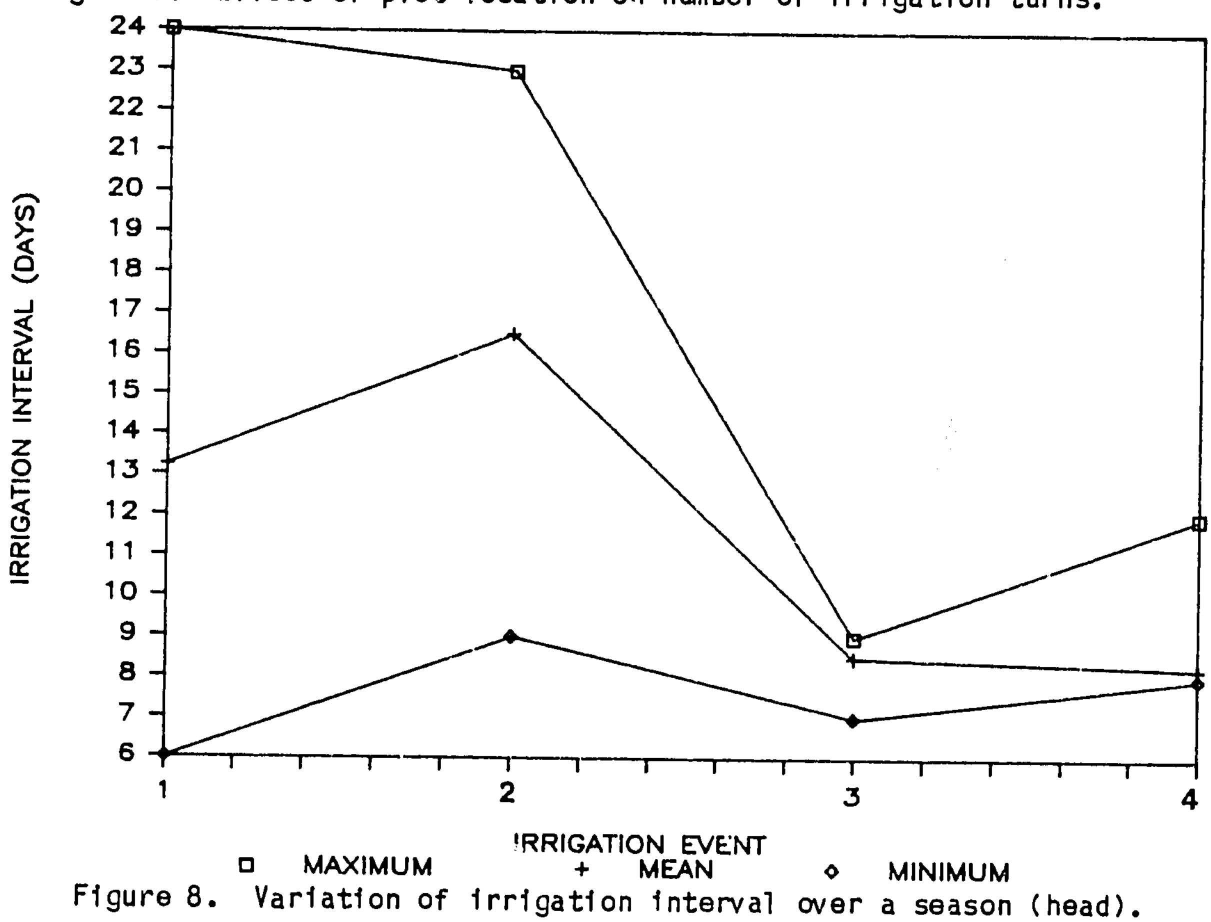


Figure 8. Variation of irrigation interval over a season (head).

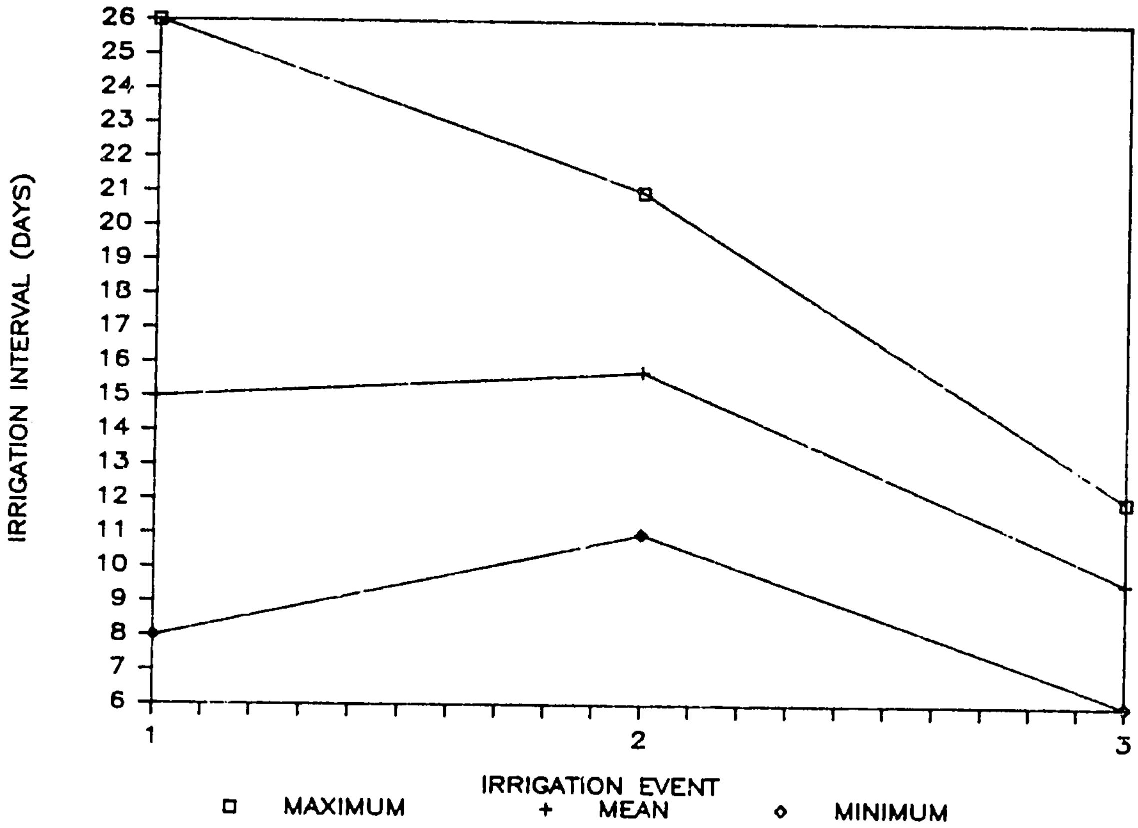


Figure 9. Variation of irrigation interval over a season (middle).

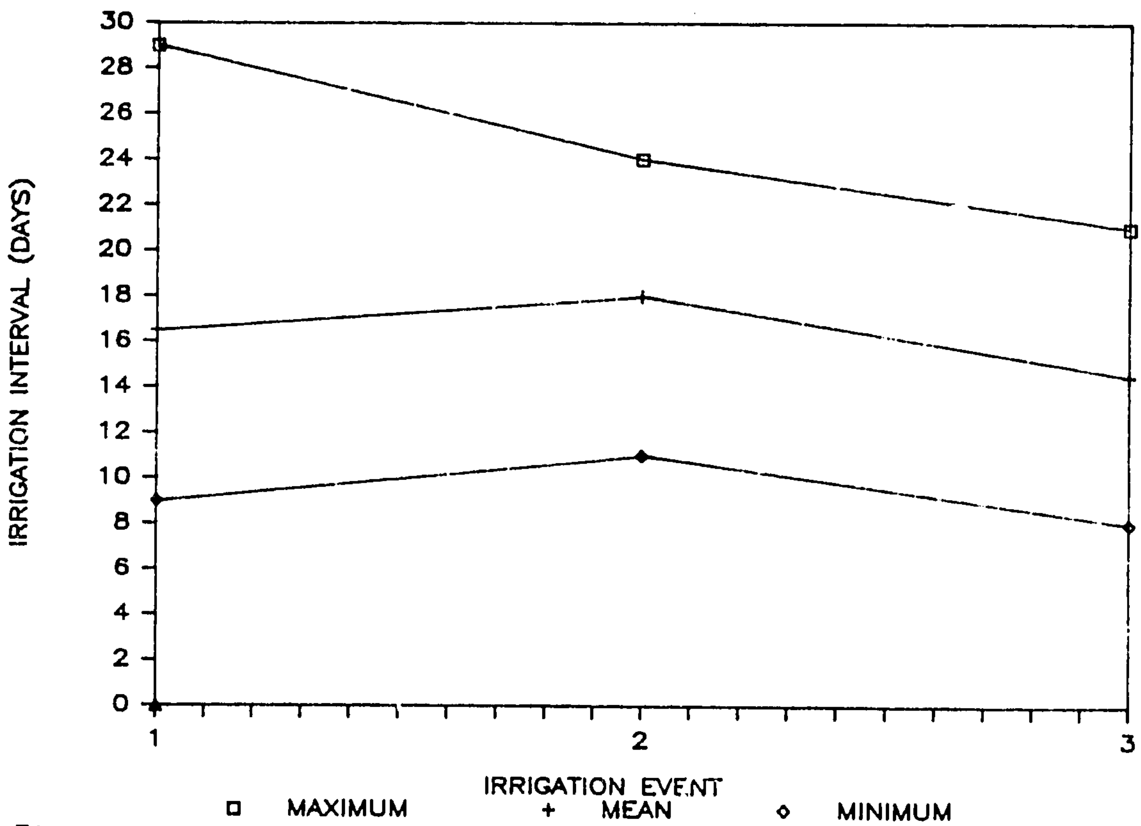


Figure 10. Variation of irrigation interval over a season (tail).

Figure 11 presents another way to assess the influence of location on irrigation intervals. For the period between any two successive irrigation events, the mean interval is shown per location. The mean interval increased from head to tail.

The distribution of the duration of delivery is shown in Figure 12. The variation of mean delivery duration, the standard deviation, and the mean duration per hectare are plotted against the plot sizes in Figure 13. Duration of deliveries ranged from 100 to 650 minutes. In relation to plot sizes, the mean and standard deviations were almost the same for all plot sizes. This shows that on a unit area basis, the larger plots had less delivery times. Since discharges did not vary much on a given day, either the larger plotholders were more efficient irrigators or they consistently underirrigated. The latter conclusion is not likely since there are no specific time limitations on a plotholder during his turn.

The field layouts in the blocks vary from very simple to a "jig-saw puzzle." Block A has a simple layout (Figure 14). The longitudinal slopes in this block averaged less than 0.1 percent. Water is delivered from a lined distributary canal to a lined head ditch, which has checks at regular intervals. Flow is blocked at these checks, or a check is improvised using a trapezoidal metal plate, a seal of plastic, and concrete blocks as support. Eight rubber siphons, each having an internal diameter of 55 mm, are then used to deliver water to the field. Siphon discharges ranged from 2.0-2.5 L/s under heads between 10-15 cm, giving a total inlet discharge of 18-20 L/s. The fields have lengths varying from 40-100 m and widths of 3-4.5 m. Field slopes were not uniform, varying 0.1 percent longitudinally and 0.2 percent across. The local name for such fields is a "bund" and the method is generally called the "oblong basin method."

Inflow times varied from 15-30 minutes depending on the field length. During an irrigation, the water did not advance uniformly due to the cross slopes. Small diversion ridges were used in the field to ensure a reasonable spread of flow. The erection of these ridges makes this irrigation method very labor intensive. Preliminary estimates of field application efficiencies ranged from 25-45 percent, depending on the crop growth stage. As part of this study, the author intended to compare actual field results to results obtained from the zero-inertia model.

Operational losses were considerable. The major component was flow to the drains due to leakage at the checks, and lost flow in periods of transfer between "bunds" and between plots. In the worst case, flow was observed to continue for 30 minutes to the drain while the farmer whose turn it was was being sought. Note that this flow is enough to irrigate the longest bund. Preliminary estimates of operational losses range from 15 to 25 percent of total flow. This is mainly due to lack of control over delivery times, and lack of flexibility in the delivery procedure.

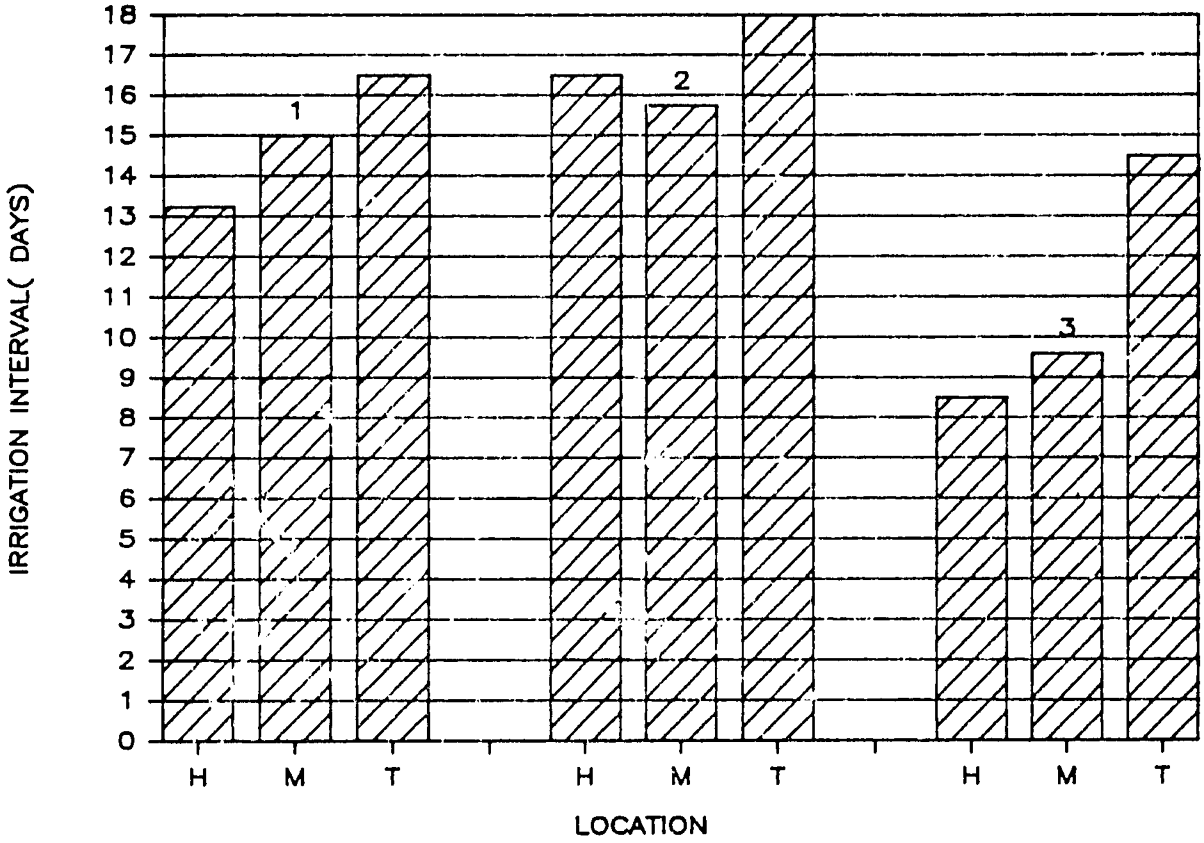


Figure 11. Effect of plot location on mean irrigation interval.

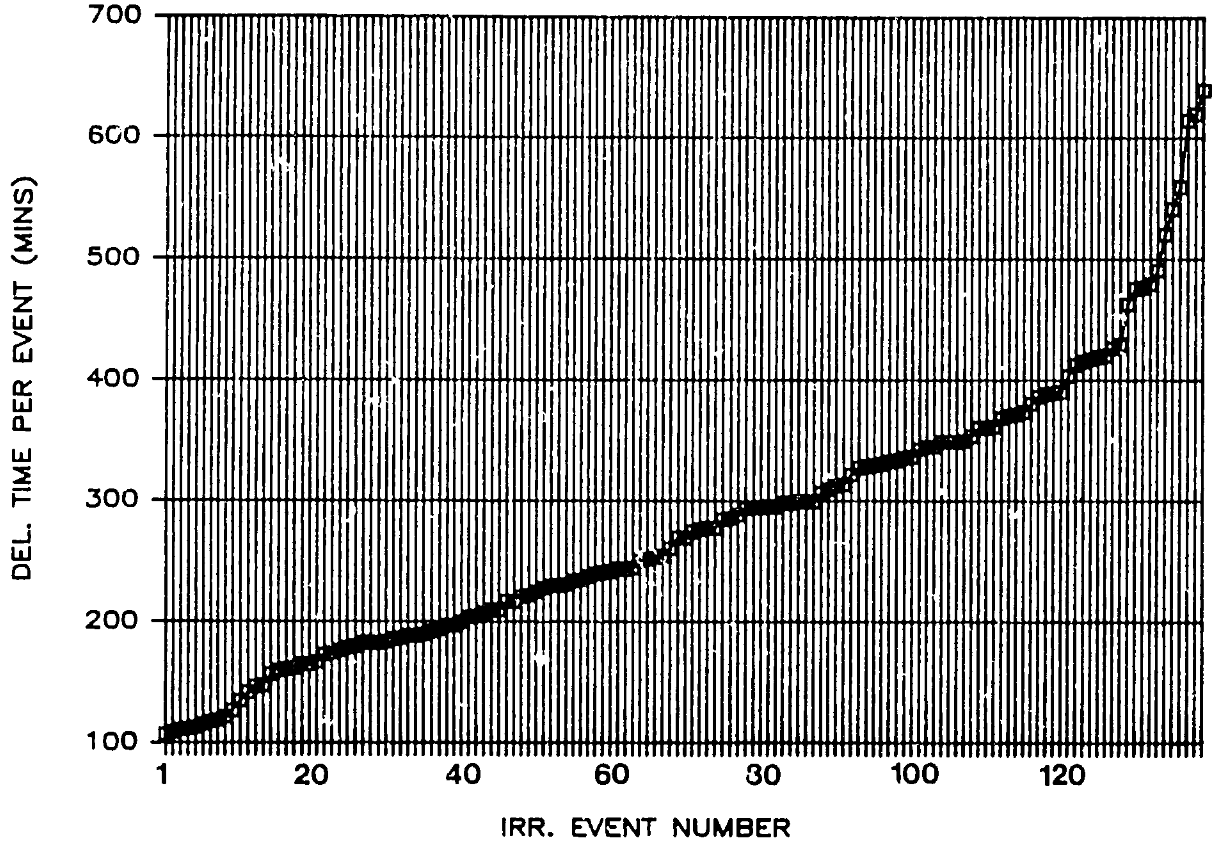


Figure 12. Distribution of duration of deliveries, Devure scheme.

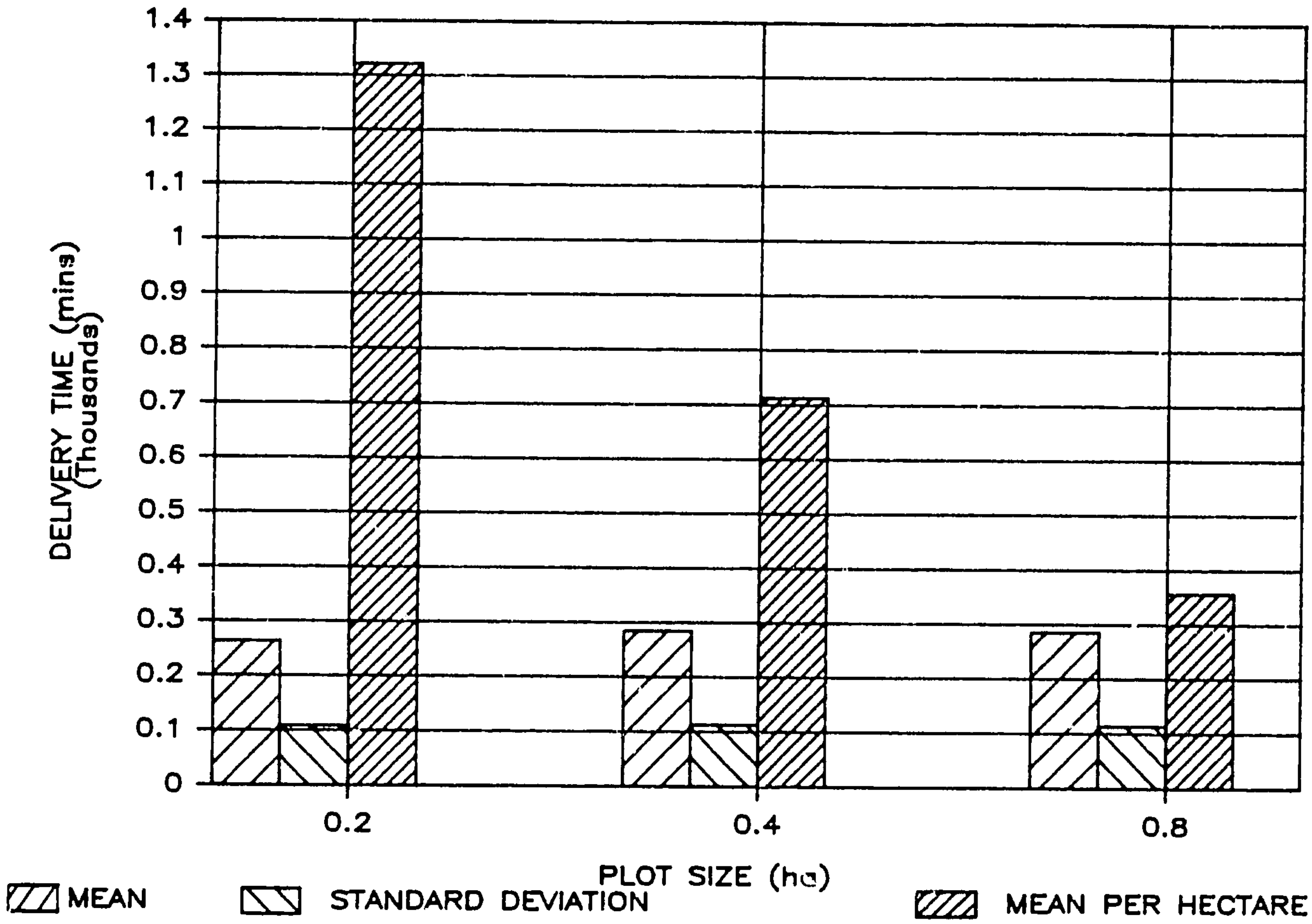


Figure 13. Variation of delivery duration with plot size, Devure scheme.

B. ADEQUACY

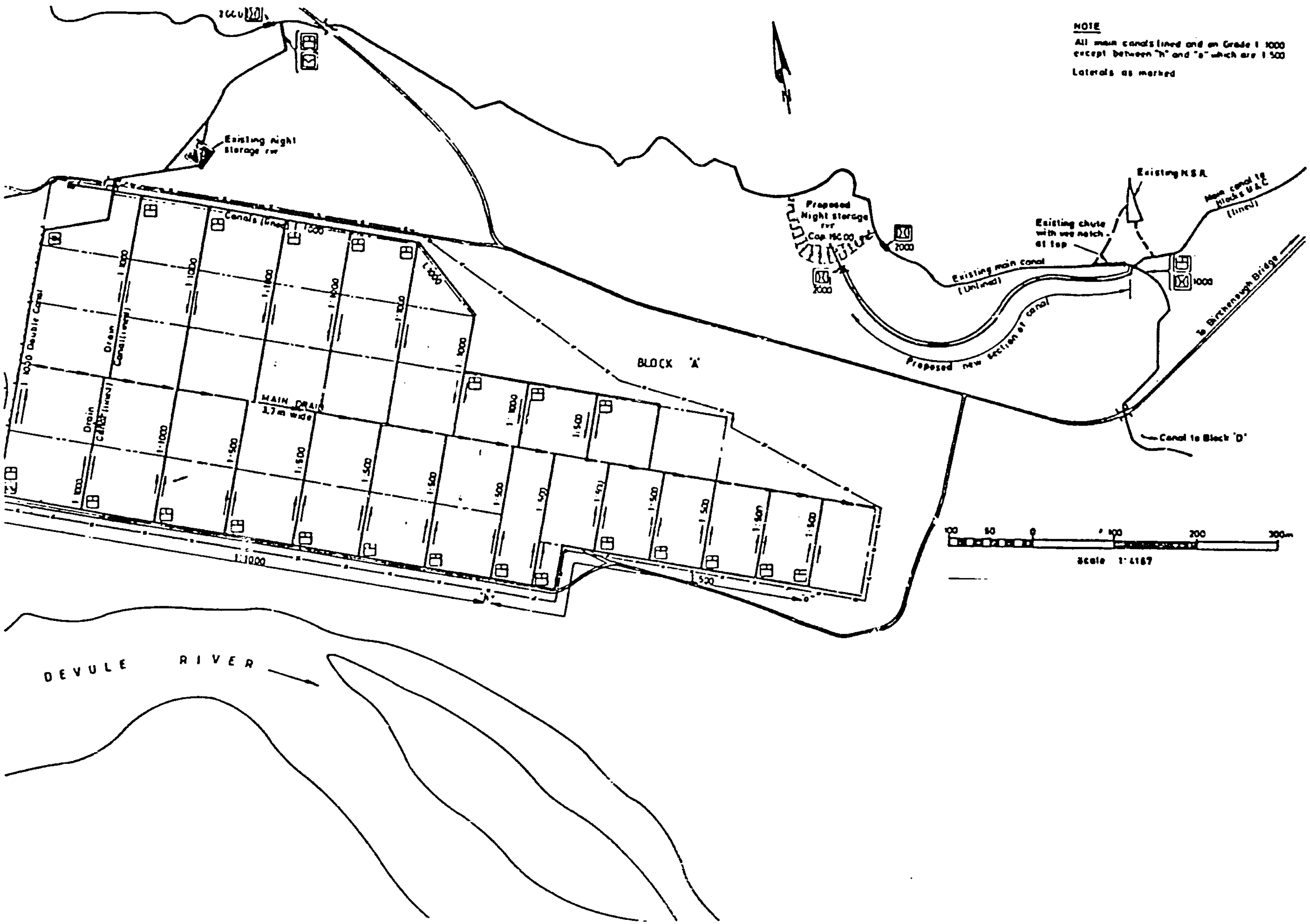
Adequacy of water supply can be analyzed in many different ways, some of which are adequacy at the source, adequacy of field deliveries, and farmers' perception of adequacy.

Adequacy at the Source

In terms of volume and discharge at the source, the available water supply is adequate for the project's water needs throughout the year. From the Devure River discharge records after the construction of the Ruti Dam (Annex C), the minimum discharge is about 1.5 m^3/s, which is adequate for the water right of 1.25 $m^3/s/50$ ha. In reality, this guarantees that a discharge at the diversion of 600-700 L/s will always be obtained.

Adequacy of Field Deliveries

Adequacy of field deliveries is variable. It depends on the location of the field and the block to which it belongs. Block A has adequate field deliveries even at the tail plots because flow at the inlet to the block is seldom below 300 L/s. The field delivery required by any field is 18-20 L/s. This can be adequately supplied by a combination



Fiaure 14. Layout of Block A, Devure scheme (Source: GOZ, 1985).

flow from the night storage dam, if working, and the gate diversions, since losses in the lined distribution canal are low and delivery is done sequentially.

Block B, which is at the tail-end of the main canal, receives less discharge (about 55 L/s) at the offtake. It has long, unlined distributary canals (the longest is about 1.5 km), which result in relatively assured field deliveries at the head of the block and serious inadequacy in supply at the tail-end. Loss rates measured in Block B distributary canals ranged from 1.5 to 2.7 L/s/100 m, which means that field deliveries at the tail-end ranged from 12 to 15 L/s.

Almost all farmers in Block B complained about water supply. It was further observed that irregularities in the distributary canal profiles caused problems in available head at the tail-end fields.

Farmers' Perception of Adequacy

Most farmers on the project believed that flow is inadequate unless the canal is full to the brim. This perception persists even in Block A where deliveries were more than adequate and a lot of waste was observed. This perception manifests itself in various ways, two of which are:

1. Frequent complaints by the farmers that they do not get enough water because part of the diversion weir is broken.

2. Resistance to paying the annual maintenance fees (which had been raised from $5.50/ha[1] (unlined) and $61.60/ha (lined) to $127.60/ha for all). Payments from Block B especially were low. Farmers in Block B also complained about the lack of lined canals. The argument boiled down to a frequently asked question. "Why should we pay as large a fee as those who get all the water (i.e., Block A)?"

   A solution could be to assign Block B fees for lining Block B canals in incremental steps using a self-help approach. This would result in improved community spirit, would by-pass the long, bureaucratic process involved in making decisions on improvements, and would guarantee post-improvement rate collection without conflict.

C. EQUITY AND RELIABILITY

Both equity and reliability varied according to the block and location of the field. Defining equity as "the ability of the system to uniformly deliver water over the system," the following comments can be made about the Devure irrigation scheme:

1. Blocks A and DI have a highly equitable distribution of water.

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[1]All dollars in this appendix are Zimbabwe dollars.

2. Block B has a high level of inequity in water distribution.

3. The project as a whole shows significant inequity in water deliveries between blocks. However, according to the old farmers, equity has greatly improved since the lower section of the main canal was lined.

Reliability can be defined as the ratio of supply to design with regard to volume, flow rate, duration, and frequency.

Using this definition, the following comments can be made about the reliability of water supply for the scheme. The source of water supply, the Devure River, is very reliable. This reliability completely depends on the functioning of the Ruti Dam. Annex C shows by looking at the "days of no flow" columns before and after the construction of the dam, that reliability of diversion flow has improved since the dam was constructed. Days of no flow in the winter (June-October) decreased from 48 days to 0 days.

Reliability at the block level, however, is variable. Even in block A, where adequacy is assured, reliability in terms of frequency is not very high. This is due to management factors and the less than desirable control on delivery times to plotholders. In the winter season under study, irrigation intervals as long as 29 days were observed in a period when there was no rain.

In Block B, reliability of field deliveries was lower. Additional factors which caused this are the following: lack of discipline in maintaining the sequential order of deliveries, "alleged" favoritism by the water bailiff, and significantly less cooperation among "neighbors."

IV. CHARACTERISTICS OF THE AGRICULTURAL SYSTEM

The summer crops are maize, cotton, and groundnuts, and winter crops are wheat, tomatoes, and sugar beans. The proportion of land historically devoted to these crops is shown in Table 3. All these crops require total irrigation in winter and "supplementary" irrigation in summer. Dryland cropping is marginal in the area and only possible with adapted crops like finger millet and sorghum.

Table 3. Historic cropping patterns in Devure scheme.

	Percent of Summer and Winter Irrigated Area						
Year	Maize	Cotton	Ground nuts	Wheat	Beans	Tomato	Vegetables
1980/81	71	22	7	19	78	3	-
1981/82	78	16	7	26	67	7	-
1982/83	72	19	9	26	71	3	-
1983/84	73	18	9	39	54	6	-
1984/85	65	14	21	-	-	-	-
Farmer Survey*	59	11	27	37	39	21	2

*1984/85 Survey Data. In summer also: 2% tomato, 1% sweet potato.
Source: DERUDE, Provincial Staff and AGRITEX scheme staff. Consultant's Farmer Survey.

From comments from farmers and management, there is a tendency to increase the proportion of groundnuts (an uncontrolled cash crop) at the expense of cotton and maize. This is explained by the occurrence of a servere groundnut shortage in the 1984-85 summer season. In addition, cotton is viewed by farmers as an intensive crop in terms of labor, inputs, and management.

In winter, a major crop is sugar beans. This is changing, however, due to serious losses caused by stem maggots. In the 1987 season, another deterrent to sugar bean production was observed. Most planting flourished during the germination and early vegetative phases, then suddenly started shriveling with the yellowing of leaves. This occurred on all the blocks and is likely to sharply decrease sugar bean yields. Some soil samples were sent to AGRITEX Provincial Headquarters for analysis. If a solution is not found quickly, most farmers are likely to stop producing sugar beans altogether in the future.

An illustration of the distribution of crop areas planted by each plotholder and the distribution of areas planted to different crops are presented in Table 4. The maize varieties grown were R200, R201, and R215, which are recommended for early maturity. The preferred variety of cotton was Albar G501, which is chosen for its drought resistance. A high yielding variety, Albar K602, is also grown to a limited extent.

Table 4. Distribution of crop areas planted by each plotholder in Devure scheme, 1984/85.

Area planted (ha)*	Percent of Respondents					
	Maize	Cotton	Groundnut	Wheat	Bean	Winter Tomato
0	3	69	52	31	35	45
0.1	0	3	0	0	0	7
0.2	17	17	21	17	14	14
0.3-0.4	41	10	14	35	28	14
0.6	7	0	0	0	10	0
0.8	24	0	10	17	7	7
1.0	3	0	0	0	3	3
1.2	3	0	3	0	3	0

*Plot sizes 0.4-0.8 ha.
Source: Consultant's Farmer Survey, 1984/85 Data.

Most of the summer crops are planted October 1 through November 15. For winter crops, the planting dates are May 1 through June 1 (tomatoes and wheat) and March 1 through April 15 (sugar beans). Usual planting and harvesting dates are shown in Table 5.

Table 5. Crop calendars for Devure Scheme.

Crop	Planting Date	Percent of Respondents	Harvest Date	Percent of Respondents
Maize	Oct	89	Jan/Feb	33
	Nov	11	Feb/Mar	52
			Apr	15
Cotton	Oct	100	Mar/Apr	100
Groundnut	Sep	76	Jan/Feb	72
	Oct	24	Mar	28
Tomato	Apr	50	Jun	40
	May	20	Jul/Aug	20
	Oct	10	Sep	20
	Dec	10	Dec	10
			Feb	10
Sugarbeans	Apr	81	Jun/Jul	80
	May	19	Aug	20
Wheat	Apr	59	Jul	56
	May	41	Aug	44

A major constraint to crop production in some blocks (B and D) is water availability and timeliness of water delivery. Poor maintenance and high canal losses, as well as poor control over delivery, lead to long irrigation intervals and crop stress. These in turn depress yields.

Fertilizer use is less than optimal. Farmers generally use less than the rates recommended by the extension staff. The motive for this seems to be the desire to minimize costs. Some wheat stands showed a yellowing of leaves, which might be an indicator of nutrient deficiency.

Animals, mainly goats and cattle, affect yields. This was, however, not a severe problem since the by-laws prohibiting unattended livestock were adequately enforced. Birds were more of a problem, especially for wheat. Blinds, scarecrows, and bells were observed being used by children to scare the birds away, especially in Block B. Occurrence of weeds varied from plot to plot and depended on the industriousness of the plotholder and his or her family. A general observation could be made that plots controlled by women head of households generally showed less weeds. Weeds were controlled mainly by hand cultivation. Pest control, especially for tomatoes, was done using chemicals and manually operated machines.

A good indicator of the performance of the agricultural system can be obtained from farmers' crop budgets. The crop yield ranges are shown in Table 6, and the returns on the farming enterprise for each crop are presented in Tables 7 to 11.

Table 6. Crop yields at Devure scheme, 1980-1985.

Season	Crop	Yield (t/ha)
Summer	Maize	3.0- 7.0
	Cotton	1.0- 2.0
	Groundnuts	2.5- 6.0
Winter	Wheat	1.5- 3.0
	Sugar beans	1.0- 1.5
	Tomatoes	20.0-35.0

Table 7. Crop budget for sugar beans per hectare at Devure scheme, 1980-1985.

Yield (t/ha)	1.5
bags/ha (91 kg)	16
Price ($422.55/t)	
Gross Output (a)	**$633.82**
VARIABLE COST	
Seed	$207.00
Innoculant	1.90
Seed dressing	1.15
Fertilizer	127.25
Insecticides	26.23
Transport to farm	13.00
Transport to market	60.00
Total Variable Cost (b)	**$436.53**
Gross Margin (a-b)	**$197.29**

Table 8. Crop budget for tomatoes per hectare at Devure scheme, 1980-1985.

Yield (t/ha)	25.0
Price ($300/t)	
Gross Output	**$7500.00**
VARIABLE COST	
Seed	210.00
Fertilizer	450.56
Insecticides	164.96
Transport to farm	42.00
Transport to market	1000.00
Total Variable Cost	**$1867.52**
Gross Margin	**$5632.48**

Table 9. Crop budget for groundnuts per hectare at Devure scheme, 1980-1985.

Yield (t/ha)	3.0
(bags/ha)	33
Price ($329.76/t)	
Gross Output	**$989.28**
VARIABLE COST	
Seed	95.22
Fertilizer	222.70
Gypsum	11.63
Insecticides	26.23
Transport to farm	24.70
Transport to market	120.00
Total Variable Cost	**$500.48**
Gross Margin	**$488.80**

Table 10. Crop budget for cotton per hectare at Devure scheme, 1980-1985.

Yield (t/ha)	2.0
(bags/ha)	11
Price ($73/kg)	
Gross Output	**$1458.20**
VARIABLE COST	
Seed	6.00
Fertilizer	191.10
Insecticides	168.50
Transport to farm	18.20
Transport to market	200.00
Total Variable Cost	**$583.80**
Gross Margin	**$874.40**

Table 11. Crop budget for grain maize per hectare at Devure scheme (1980-1985).

Yield (t/ha)	5.0
(bags/ha)	55
Price ($178.80/t)	
Gross Output	**$894.00**
VARIABLE COST	
Seed	18.73
Fertilizer	301.30
Insecticides	6.80
Transport to farm	13.50
Transport to market	204.00
Total Variable Cost	**$544.33**
Gross Margin	**$349.67**

V. STRENGTHS AND WEAKNESSES

A. STRENGTHS

Extension Training

The ratio of extension workers to farmers is 1:60, which is better than the national average of 1:800. Moreover, the extension officers are very motivated and have good access to in-service training programs at both provincial (ROWA, Mutare) and national (Harare) levels.

Water Supply and Quality

There is adequate and reliable water supply from the Devure River. The Ruti Dam upstream has dampened the steep variations of the natural river flows.

Guaranteed Markets

Guaranteed markets and on-site collection facilities exist for some of the crops cultivated. The local Cotton Marketing Board (CMB) depot is only about 5 km away from the farthest plot. All inputs for tomato production are supplied by the LEMCO Canning Company, which also buys the tomatoes on the field at harvest time. In addition, private tomato contractors are available at field level to provide an alternative, giving the farmers a limited degree of competition for their products.

Farmer Participation

Farmer participation in decision making on issues affecting the scheme is increasing. On one hand, this is a positive development which might, in the long-run, make the goal of a farmer-managed scheme feasible. However, according to the extension staff, increased farmer participation has also led to "relative" indiscipline and inefficiency. The key word is "relative" since the extension staff felt that during the days of rigid control over the production process by management, everything ran more efficiently.

B. WEAKNESSES

Sprinkler Section

The sprinkler system is inoperative due to lack of maintenance and ineffective equipment.

System Design

In blocks with unlined canals, the actual system layout is unsatisfactory. Slopes are variable, field elevations exceed the elevations of field canals, and most field canals are in a high state of disrepair.

Conveyance System

Loss rates in blocks B and C are very high. This, coupled with long distributaries (e.g., about 1.5 km), results in inadequate and inequitable distribution of the water supply.

Irrigation Scheduling

The "laissez faire" approach used in water deliveries between plots leads to excessive water losses at the field level. It is estimated that about 10-15 percent of total flow in Block A, for example, ends up directly in the drain due to inattentiveness of the irrigator.

VI. CONCLUSIONS

Some general conclusions resulting from this activity follow.

1. The network resulting from the Joint Field Workshop proved very valuable in carrying out this activity.

2. Planning for research activities to follow the Joint Field Workshop should be more detailed.

3. Seasonal detailed data for a small-scale irrigation project is now available.

Further, the following specific technical conclusions can be made about the Devure irrigation scheme.

1. It serves as a vital source of food, employment, and economic development for a wide area.

2. It has a very reliable and adequate source of water supply.

3. Certain blocks (B and C) need rehabilitation to improve production outputs.

4. There is a serious need for improving irrigation management, especially in delivery scheduling and on-farm water management. Losses in conveyance and distribution canals are high, and improvements in water management could be used to expand the project area and provide plots for farmers on a long waiting list (about 500).

5. Farmer participation in the management of the project should be encouraged. This would facilitate the divestment of AGRITEX control over the project.

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VIII. ANNEXES

ANNEX A

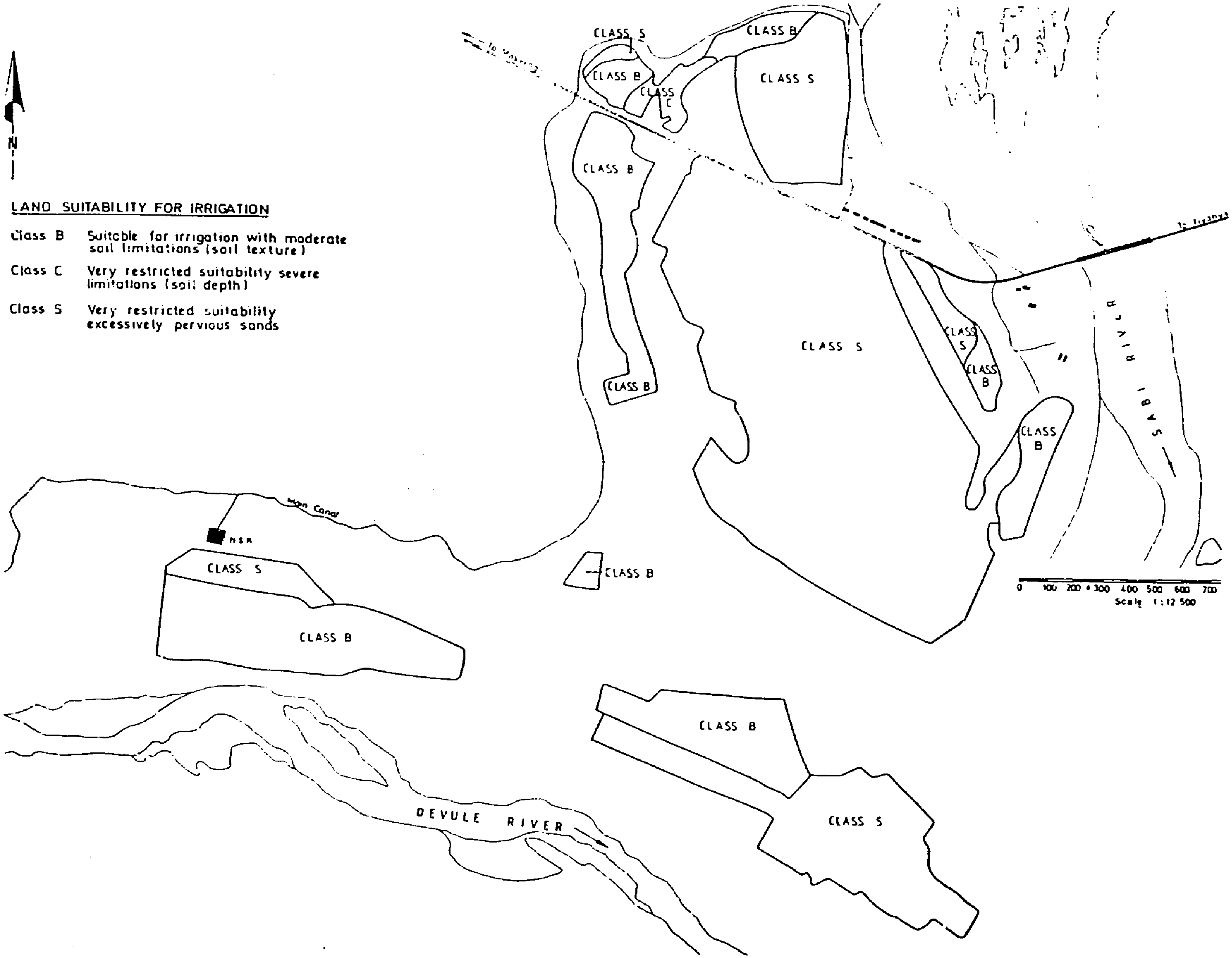
TIMETABLE OF ACTIVITY

Date	Activity	Comments
06-03-87	Depart Fort Collins	
06-04-87	Arrive London	
06-05-87	Depart London	
06-06-87	Arrive Harare	
06-08-87	Administrative preparations for field work	Encountered problems in obtaining permission to begin field work. With help from Mr. Eric Witt, USAID, this was resolved on 06-22-87.
06-23-87	Depart Harare	
06-23-87	Arrive Mutare	
06-24-87	Met Mr. S. Gimani, provincial irrigation officer	
06-24-87	Depart Mutare	
06-24-87	Arrive Birchenough Bridge	
06-26-87	Return trip to Mutare	Telephone contact Dr. Podmore, CSU
07-03-87	Return trip to Mutare	Sent report via DHL
07-07-87	Return trip to Mutare	Made travel arrangements to Botswana
07-16-87	Depart Birchenough Bridge	
07-16-87	Arrive Harare	
07-17-87	Depart for Botswana	

07-17-87	Arrive Gaborone	Purpose was to break stay in Zimbabwe into two periods of six weeks to satisfy immigration requirements.
07-22-87	Depart Gaborone	
07-22-87	Arrived Harare	
07-23-87	Seminar, University of Zimbabwe	Presented seminar on "Computer Use in Irrigation Management"
07-24-87	Depart Harare	
07-24-87	Arrive Birchenough Bridge	
09-04-87	Depart Birchenough Bridge	
09-04-87	Arrive Mutare	
09-05-87	Depart Mutare	
09-05-87	Arrive Kwekwe	
09-06-87	Depart Kwekwe	
09-06-87	Arrive Harare	
09-07-87	Secondary Data Collection	
09-11-87	Depart Harare	
09-12-87	Arrive Amsterdam	
09-18-87	Depart Amsterdam	
09-18-87	Arrive Denver/Fort Collins	

ANNEX B

SUITABILITY OF LAND FOR IRRIGATION IN DEVURE SCHEME
(Source: GOZ, 1985)



ANNEX C

DEVURE RIVER FLOWS BEFORE AND AFTER RUTI DAM WAS CONSTRUCTED

CATCHMENT AREA - 8200.00 km2 NOTCH CAPACITY - 740.508 cumecs
LAT - 19.54 S
LONG - 32.08 E
RECORDING STATION - DEVULI CHISURGWE FLUME

Month	Before (1970/71) flow in m3/sec				After (1982/83) flow in m3/sec			
	Maximum	Minimum	Mean	Days No Flow	Maximum	Minimum	Mean	Days No Flow
Oct	13.100	0.000	1.180	12	7.540	1.980	2.470	0
Nov	26.800	0.000	4.500	0	32.400	1.890	2.730	0
Dec	255.000	0.393	16.800	0	17.400	1.890	2.510	0
Jan	343.000	14.400	79.600	0	8.180	1.890	5.180	0
Feb	31.200	6.320	15.800	0	649.000	0.752	13.600	0
Mar	25.800	1.190	3.920	0	285.000	0.752	9.070	0
Apr	11.000	0.623	2.030	0	3.860	0.686	3.380	0
May	5.200	0.022	1.330	0	3.490	1.040	1.660	0
Jun	1.960	0.128	0.491	0	3.490	2.280	2.600	0
Jul	0.393	0.007	0.086	0	2.700	1.440	1.790	0
Aug	0.007	0.000	0.005	6	2.700	1.610	2.060	0
Sep	0.000	0.000	0.000	30	5.030	0.890	3.270	0

APPENDIX B

IRRIGATION WATER-LIFTING IN ZIMBABWE

by

Peter Fraenkel

prepared for

Consortium for International Development

and the

United States Agency for International Development

DRAFT
March 1987
Ref: 025

1. BACKGROUND

This report has been prepared by Peter L. Fraenkel of I.T. Power, Inc. (Washington, D.C. and Eversley, U.K.) for the Agency for International Development. The author visited Zimbabwe from 11 through 27 February 1987, to cooperate with a five-member mission of the Water Management Synthesis Project organized by the Consortium for International Development (Tucson, Arizona).

The Scope of Work for the author's mission is set out in a telex originating from AID S&T/EY, reference State 392992 addressed to the US Embassy, Harare, (see Annex 1). It primarily required:

* Identification of existing irrigation power sources at selected project sites and identification of constraints affecting their operation.
* Determination of irrigation pumping energy requirements as a function of season and of typical crops.
* Studying the efficiency of such systems.
* Determination of energy costs for pumped water and their effect on irrigation economic viability.
* Determination of frequency of use of such systems.
* Determination of infrastructural arrangements (for O&M) and any related constraints, etc.
* To look at any innovative power supply systems of relevance to small-scale irrigation in Zimbabwe.

ST/EY also appointed an economist, Mr. Ron D. White, who visited Zimbabwe immediately prior to the author's visit to look at broader, energy-related issues connected with irrigation. A draft copy of Mr. White's report (Ref. 1) was made available to the author of this report by AID in Harare, but unfortunately there was no possibility to liaise effectively with Mr. White as the missions did not overlap.

2. ITINERARY

The author's field trip was completed separately from that of the other members of the mission, because most of the projects being studied in depth by the other members were gravity irrigation schemes of limited relevance to this particular study, and all the schemes having any elements of pumped irrigation had already been visited by the rest of the team prior to the author's visit. Therefore, it was decided, in consultation with the rest of the team, to select a number of projects involving pumped irrigation, located close to the projects that were the primary subject for study in the southern Manicaland region. All projects being studied were located within government-sponsored Communal Lands; private sector irrigation projects were not considered and in any case are generally much larger in scale than would be relevant.

The routing used by the author is indicated in Figure 1, which also shows the locations of the sites visited. Table 1 below indicates the salient characteristics of the sites visited.

Table 1: Site visited.

Location	Area	Type of Supply
1. Nyanyadzi	414 ha	Gravity + 4x30 hp diesels & 2x spark ignition engines
2. Tawona	151 ha	3 x mains electric 45 kW each
3. Mutema	237 ha (incl. 183 ha sprinkler)	4 x submersible borehole pumps 55, 37.5, 110 & 75 kW electric
4. Rupungwana	10 ha	1 x diesel 30 hp
5. Chisumbanje	approx. 2,000 ha	4 x electric 2x110 kW 2x175 kW

The installation at Chisumbanje was not strictly part of this study, as the S.O.W. called for a study of four systems and clearly the smaller systems were of most interest. However, the opportunity was taken for a brief visit to the large scheme at Chisumbanje since it was directly on the author's itinerary.

Although the individual farmer's plots on these schemes are generally quite small, it is clear that even the smallest is far from being "micro-irrigation" and most are relatively large schemes. Although the author would have preferred to see more small schemes, these are rare and many of them are not operational. The smallest are on the order of 10-15 ha.

There are occasional private initiatives to irrigate small isolated plots to grow cash crops, mainly using buckets or watering cans, but occasionally using small gasoline or diesel fueled pumps. These are, however, quite rare and difficult to identify on a field trip since they are not officially approved of and, hence, there is no official record of their locations. As the field trip took place within the rainy season, any small-scale private irrigated plots were difficult to distinguish from rainfed cultivation at the time of this mission. Some further comments are given on this topic later in this report.

The author also met with a number of people from various Zimbabwean institutions, and these are listed in Annex 2, together with details of the other members of this mission.

The total distance covered on the field trip was 1,950 km, hence it would have been difficult within the time available to extend the tour to take in any further areas of the country. Probably the only area with significantly different irrigation problems would have been Matabeleland, near the Botswana border (on the edge of the Kalahari region), but even had more time been available, it was understood that travel by foreigners in that area was not encouraged by the authorities due to occasional security problems in the region.

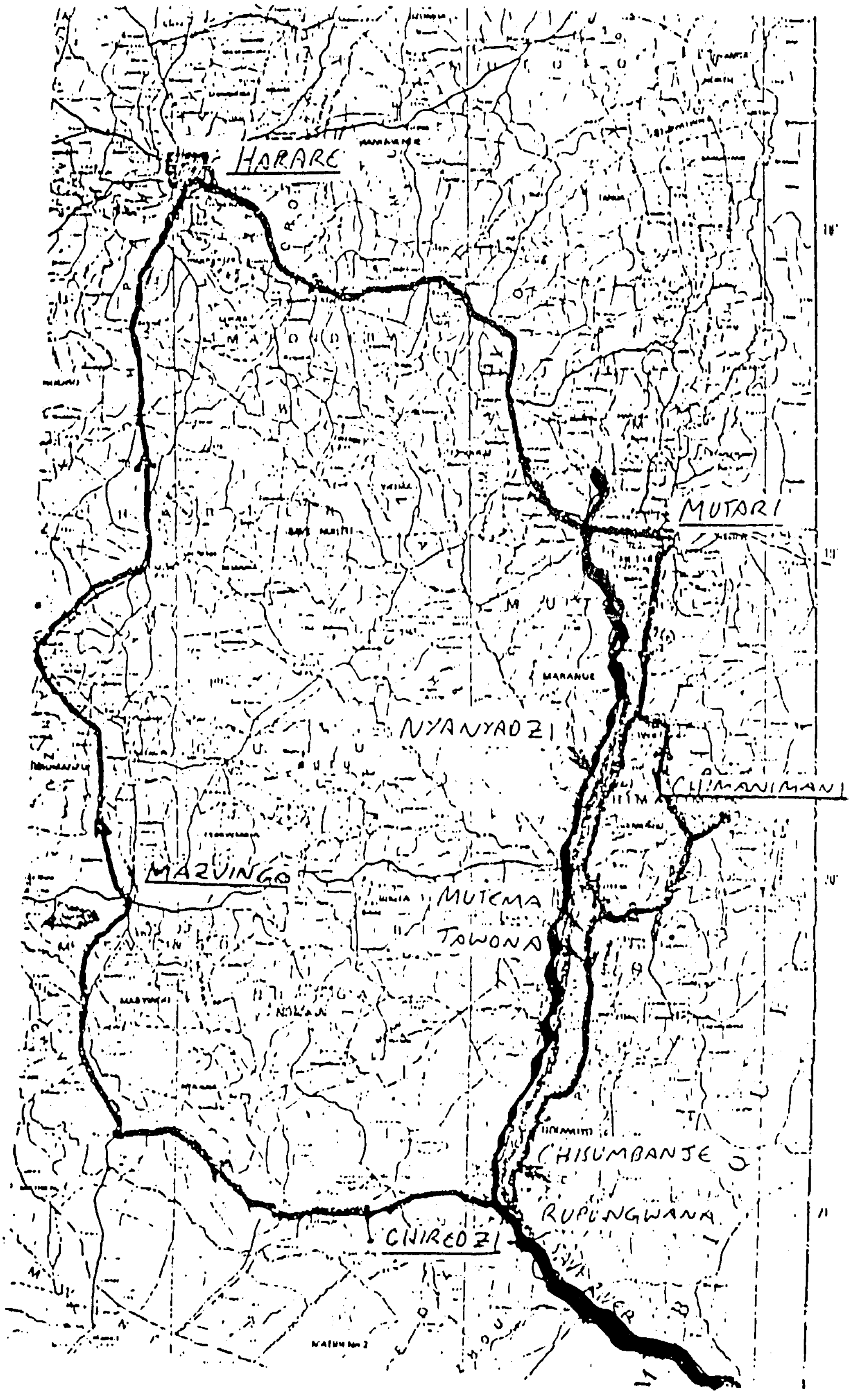


Figure 1. Route taken, sites visited, major towns, Save River.

A more detailed description of the water abstraction system at each site visited is given in Annex 3.

3. EXISTING WATER-LIFTING SYSTEMS

3.1 Types of system in use and government policy

The only types of irrigation system in general use in Zimbabwe are gravity, mains electricity, or diesel.

Table 2 (from Ref. 5) indicates the present scope of irrigation in Zimbabwe, and shows that the Communal Lands, of interest for this mission, account for only about 10 percent of irrigated land areas in the country, the overwhelming majority being large-scale commercial farms and estates. Figure 2 indicates the locations and sizes of all Communal Lands irrigation schemes (Ref. 5).

Present policy for future development of irrigation is based on the over-riding government priority to minimize foreign exchange requirements. Therefore, mechanized systems based on imported components cannot easily be obtained and there are major difficulties in providing imported spare parts or even consumables for regular maintenance of existing engine powered lift irrigation systems. However, despite problems with other imports, diesel fuel and gasoline were generally readily available, even in remote places, at the time of the mission. No fuel shortages had been recently experienced or were expected, although the author was told that the foreign currency allocation for the import of engine lubricants had recently been drastically reduced (Ref. 2) and would no doubt lead to shortages in the near future.

Therefore, it is government policy to promote gravity irrigation schemes rather than pumped schemes wherever possible. Where pumping is unavoidable, the preference is to use mains electricity for reasons of both economy as well as to reduce operational problems (Ref. 3).

Table 3, which relates purely to Communal Lands schemes, (Ref. 5) shows a breakdown of abstraction methods on the Communal Lands.

It can be seen from the table that with the exception of Matabeleland South, diesel pumped schemes are comparatively rare, and they are tending to be phased out in favor of mains electrification.

3.2 Mains Electrification in Zimbabwe

The reason mains electrification makes sense in Zimbabwe is that, unlike in most developing countries, there is a well developed grid (see Figure 3) covering most of the country. Moreover, electricity tariffs, particularly for farmers, are unusually low by international standards giving typical costs per kWh in the region of 2 US cents[1], Figure 4 indicates how this varies, depending on various factors, but decreases with increasing electricity use.

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[1]US $1.00 ~ Z-$1.67 (March 1987).

Table 2. Irrigation in Zimbabwe.

Category	Approximate Area Under Irrigation (ha): Total in Zimbabwe [1]	Natural Regions IV & V only	Main Crops and Other Notes [2]
Large Scale Commercial Farms -perennial crops	50,000	32,000	Sugar cane (32 000 ha) & citrus (1 500 ha) mainly on large company estates. Coffee (6,500 ha) pasture (3,500 ha) and fodder crops (2,300 ha), mainly on large private farms.
- single cropped area	24,300	5,000	Cotton (18,200 ha) and tobacco (5,300 ha), mainly on large private farms.
- double cropped area	45,000	8,000	Grain maize (27,400 ha) groundnuts (3,600 ha) & soyabean (14,000 ha) in summer. Wheat (37,300 ha), barley (5,500 ha), potatoes (1 300 ha) & beans (400 ha) in winter.
Small Scale Commercial Farms	75	0	55 ha irrigated in summer, 75 ha in winter.
Commercial Farming Area - Sub-total	119,375	45,000	180% estimated cropping intensity.
ARDA Estates	9,900	5,350	1982/83 cropping intensity was about 138%. 870 ha of perennial crops (tea: 470 ha). Cotton (6,900 ha) & maize (780 ha) in summer, wheat (2,600 ha & barley (470 ha) in winter.
Small Scale Irrigation Schemes	3,075	2,388	1,886 ha usually irrigated in winter, 2,967 ha in summer.
Small Private Schemes on Communal Lands.	400	0	Mainly vegetables, probably at 200% cropping intensity.
Communal Lands - Sub-total	13,375	7,738	145% estimated cropping intensity.
TOTAL	132,750	52,738	177% estimated cropping intensity.

Notes: [1] *The irrigated crop areas for large scale and small scale commercial farms are based on the 1982 edition of Crop Production of Commercial Farms (CSO, 1982c). It has been assumed that all the area under wheat, barley, potatoes and beans in winter is also cropped using supplementary irrigation in summer. The ARDA figures are for 1983/84, on 17 out of 18 estates.*

[2] *The areas and intensities refer to the national figures.*

Sources: CSO, 1982c for commercial farming area.
World Bank, 1983b for small private schemes.
ARDA, personal communication.
GKW/HTS/BCHOD for small scale irrigation schemes

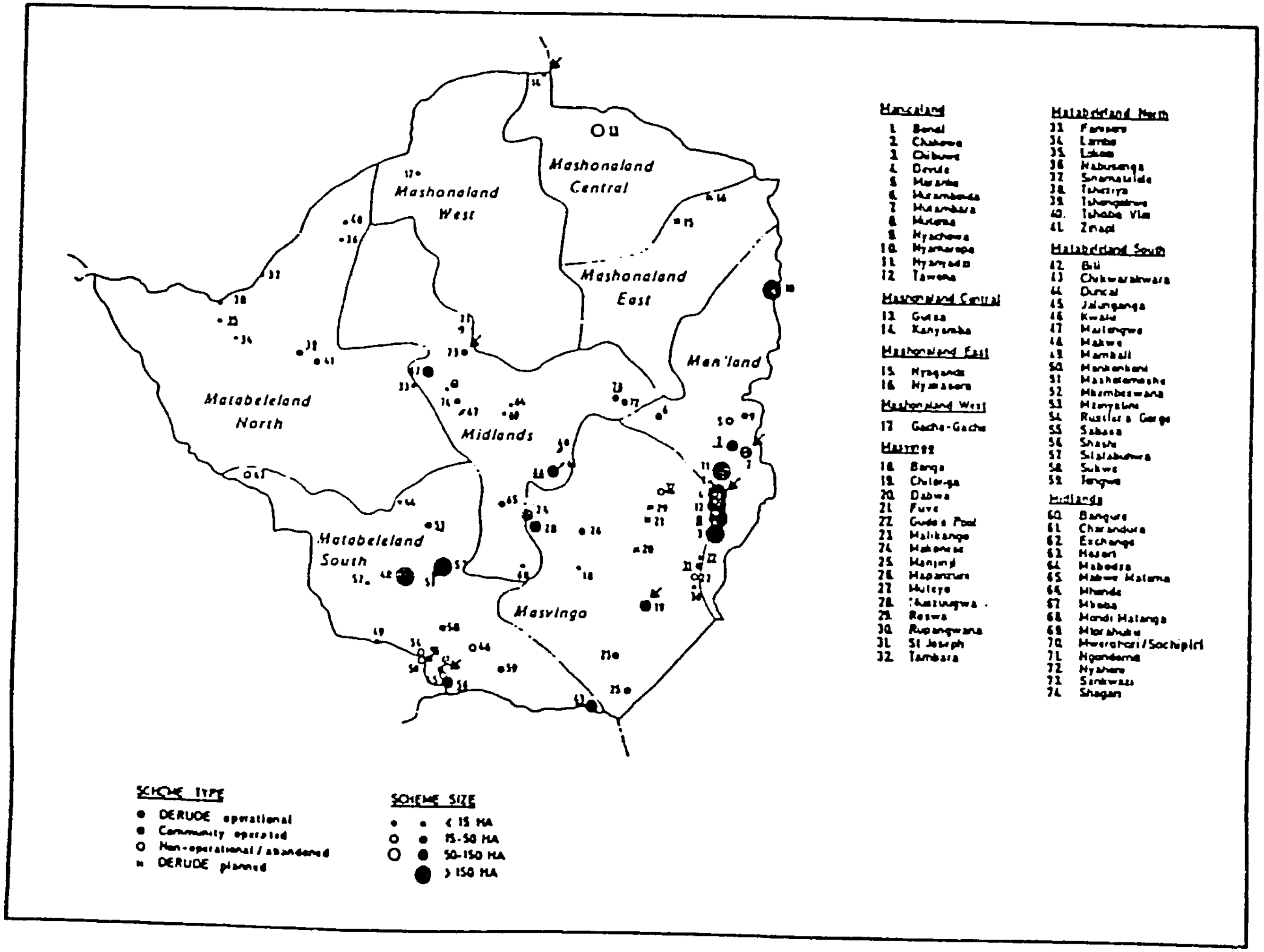

Figure 2. Small-scale irrigation schemes in communal lands.

Table 3: Water abstraction methods on communal lands schemes, by province.

Abstraction method	Manicaland	Mashonaland	Masvingo	Matabeleland North	Matabeleland South	Midlands	Total
Gravity	5	0	2	4	4	11	26
Gravity + electric pump	1	0	0	0	1	0	2
Gravity + diesel pump	2	0	0	1	0	0	3
Electric pump only	2	0	3	1	1	3	10
Diesel pump only	0	1	3	1	6	1	12
Total	10	1	8	7	12	15	53

The government is justified in promoting the increased use of mains electricity since the main source of power is the giant Kariba Hydro-electric scheme, built in the 1960s, which is supported by thermal power stations at Hwange fueled from indigenous coal. The two power stations at Kariba have a generating capacity of about 1,500 MW, of which Zimbabwe uses about two-thirds and Zambia one-third. Hwange 1 thermal station is rated at 480 MW and Hwange 2, offering a further 400 MW, is scheduled to come on-stream later this year (Ref. 4).

Even when Zimbabwe's extremely large generating resources (by African standards) are used to capacity, the presently under-utilized Cabora Bassa scheme in neighboring Mozambique offers further substantial capacity in electrical supply capacity for the region. Hence, electricity production makes little demand on foreign currency and utilizes resources with significant capacity for expansion. Moreover, Zimbabwe's indigenous proven coal reserves have been estimated at 30,000 million tons, which at the current rate of usage (3 million tons/annum) would last 10,000 years! (Ref. 4).

Electricity, apart from being plentifully available, is also relatively inexpensive, both in production costs and to the user, so that conventional oil-fueled or unconventional renewable energy based alternatives are all significantly more expensive to the user financially and to the country (in terms of foreign exchange) economically.

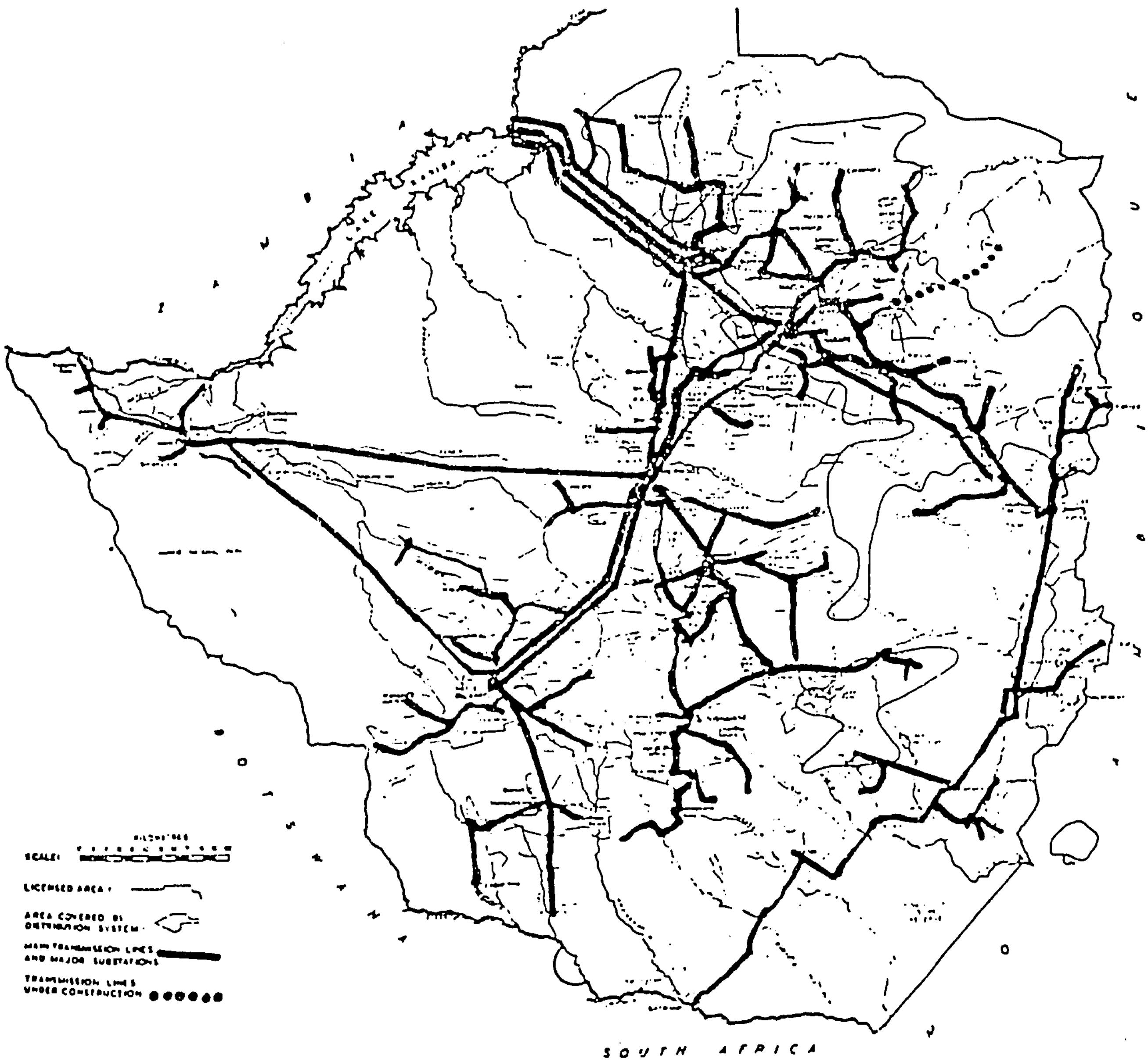

Figure 3. Electricity supply network (1985).

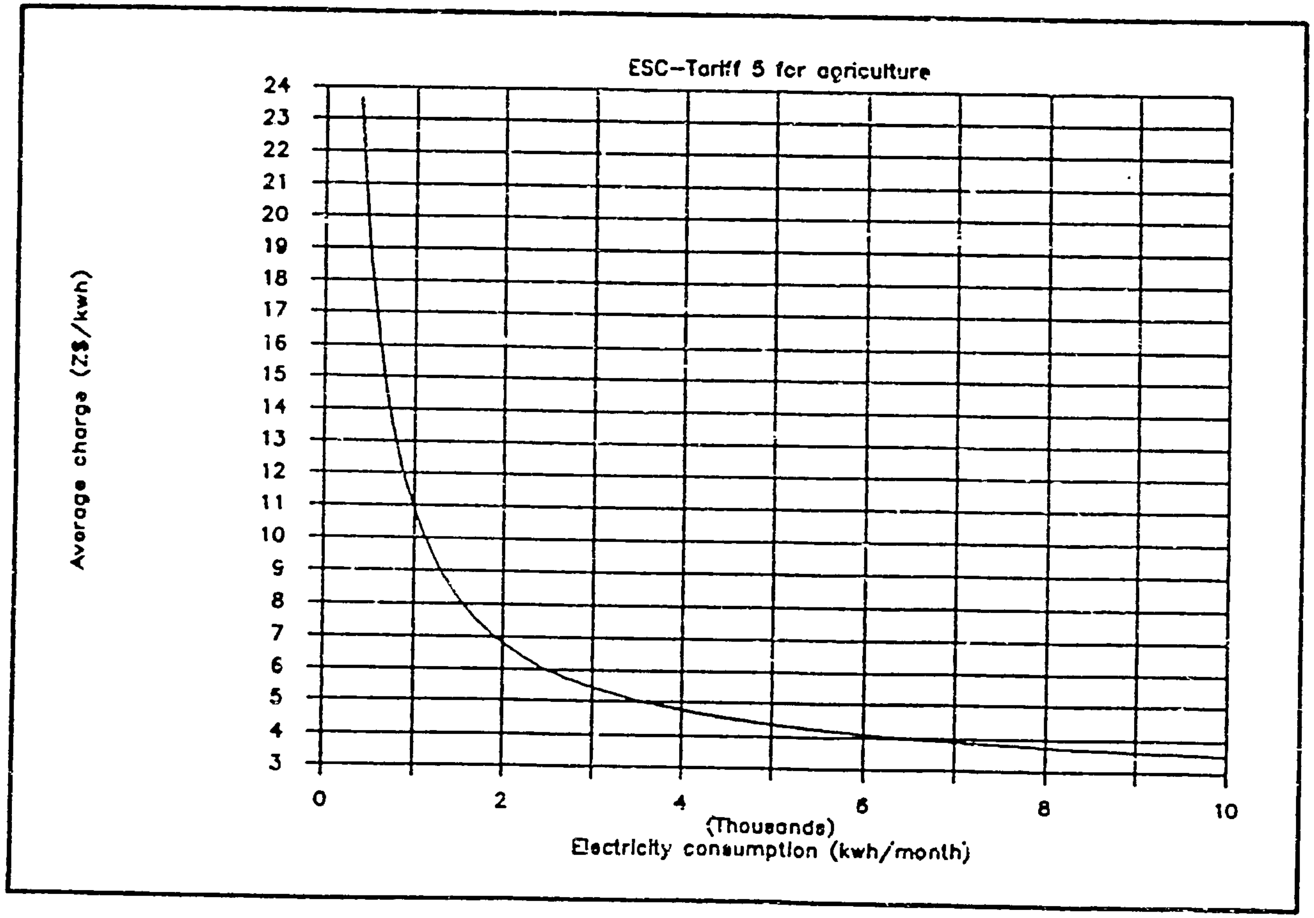

Figure 4. Average electricity charge.

3.3 How Irrigation in Zimbabwe is Organized

There are no natural lakes of any size in Zimbabwe, and surface water is scarce. Rainfall is highly seasonal, being confined to the period October through April. Rainfall varies from less than 500 mm on average per annum in the Lowveld region to over 1000 mm on higher ground. There is a close correlation in Zimbabwe between height above sea level and rainfall. Moreover, the variability of rainfall from year to year is high, with frequent drought years which make rainfed agriculture risky, especially in the lower-lying, drier parts of the country.

There has been a long tradition of conserving rainwater through the use of dams; Zimbabwe has over 7,000 dams, which makes it one of the most advanced countries in the Third World in water conservation. There is strictly enforced legislation on water extraction rights, which obviously constrains the use of irrigation by farmers.

Although agriculture accounts for only about 20 percent of GDP, it is by far the most important economic activity in Zimbabwe, with 80 percent of the population dependent on it. This sector also provides about 40-50 percent of total exports.

Irrigation is already widely practiced, with very large irrigation schemes being in use in the commercial farming sector. In particular, there are some extremely large irrigated sugar estates in the south-eastern Lowveld in the Triangle, Hippo Valley, Chiredze region. Zimbabwe exports 100,000 to 200,000 tons of raw sugar annually. Incidentally, this sugar industry contributes as a renewable energy resource in two ways. Firstly, the refineries are energy self-sufficient and produce a small surplus of electricity by burning bagasse for steam-powered electricity generation (as is normal practice in large-scale sugar industries). Secondly, ethanol is produced as a by-product of the sugar industry and is blended with gasoline. All automotive gasoline sold throughout the country consists of this ethanol blend. Other important large-scale irrigated commercial crops are winter wheat and grapes and citrus fruit. However, it is understood that only about 12 percent of potentially irrigable land is currently under irrigation (Ref. 2).

Smaller scale irrigation is practiced in a number of areas. Some schemes date back to the 1930s, and many were introduced during the 1950s and 1960s. Most such schemes are by gravity from river diversions or dams, but many are supplemented by pumping. The majority of those in the drier lowveld region, used by small farmers, are on the so-called "Communal Lands." These are areas of the country of generally second class agricultural land used originally during the colonial era largely to resettle people away from the better quality land of the highveld where most commercial farming takes place.

Because the Communal Lands tend to be of poorer quality or in lower-lying and dryer areas, irrigation offers one of the few routes to increasing the productivity and the economic well-being of these relatively poor and backward regions of the country. In fact, although this mission took place during the period when rains are normally expected, the 1986-7 rainy season had been exceptionally dry, and nowhere more than in the lowveld where almost no rain had fallen and virtually all rainfed cultivation had failed. At the time of the visit, the drought was being reported as a catastrophe for a large proportion of the population on the Communal Lands (except, of course, those fortunate enough to benefit from irrigation schemes). This effectively emphasized the potential importance of extending irrigation to take in a wider clientele.

The drier lowveld irrigation schemes more often demand at least an element of pumped water supply because the main water source, the Save River and its tributaries, varies drastically in flow through the seasons and from year to year. Hence, the level from which water needs to be drawn can fluctuate considerably and make gravity diversions ineffective when the river more or less dries up. Hence, a number of schemes use sand extraction from the river bed or even boreholes in order to obtain water, even when there is no surface river flow, and these obviously have to be pumped.

Most small-scale irrigation on Communal Lands is administered by the government's agricultural support services. The primary government agencies with an interest in irrigation are as follows:

Ministry of Energy and Water Resources and Development

This Ministry carries the responsibility for the provision of both water and energy supplies throughout Zimbabwe. In the context of irrigation, agencies of this Ministry are responsible for the provision and maintenance of dams and water conveyances to the field edge (i.e., water catchment and primary conveyance infrastructure). With pumped schemes, the Ministry is responsible for the provision and maintenance of energy supplies, engines, and/or motors and pumps. A number of engine-powered lift irrigation schemes still come under the Ministry, but the tendency is to introduce mains electrification wherever possible due to increasing difficulties in maintaining and servicing imported engines and the relatively much better reliability of electric motors, some of which are manufactured in Zimbabwe.

A related area of activity for this Ministry is the provision of drinking water supplies, many of which need to be pumped.

Agritex

Agritex is the agricultural extension services of the Ministry of Agriculture and is largely responsible for planning, monitoring and promotion of irrigated cultivation by small farmers.

ARDA

ARDA (the Agricultural & Rural Development Authority) is a parastatal corporation which comes under the jurisdiction of the Ministry of Lands, Resettlement and Rural Development (MLRRD). Some of ARDA's irrigation projects are both large and profitable (e.g., Middle Save covering some 2,000 ha of Save River bank).

DERUDE

This is the Department of Rural Development (in the MLRRD), which administers existing communal irrigation schemes, plans future ones, and is responsible for collecting fees from farmers for the provision of irrigation water. DERUDE runs a committee to monitor and grade the effectiveness of farmers' cooperative schemes for managing and using irrigation water.

4. IRRIGATION PUMPING ENERGY REQUIREMENTS

The energy requirements for irrigation are a function primarily of the quantity of water required and the pumping head. Both of these vary seasonally, being at a maximum in the dry season when crop irrigation water requirements are highest and the river levels and watertables are at their lowest.

4.1 Typical Crops and Crop Water Demand Patterns

The much more detailed report from the other members of the team deals in detail with agricultural and soils aspects, so this section will only give an indication of typical cropping patterns, seasonal demand variations, etc.

Table 4 indicates a typical cropping pattern in the Save River valley, for the scheme at Mutumbara, a gravity scheme close to the location on the author's itinerary of Tawona and Mutema. A summer crop of maize and cotton and a winter (dry season) crop of wheat, beans, peas and tomatoes is illustrated. It can be seen that a peak irrigation water demand of 213 mm in January on average (and up to 257 mm in January is statistically probable once in 60 years).

4.2 Typical Water Abstraction Heads/Flows and Energy Requirements

Pumping heads obviously vary from site to site, but are typically in the range from 5 to 15 m (static head) and perhaps up to 25 m to allow for conveyance heads. Variations of river level of 5 m or more can occur. Obviously, significantly higher heads of from 20-40 m must be added where sprinklers are used. Naturally, since most schemes are gravity supplied, various forms of flood irrigation are the most common method of water application. However, sprinklers are widely used in the larger commercial sector irrigation schemes, such as on major sugar estates, and centre pivot systems are beginning to be introduced and are actually manufactured/assembled in Zimbabwe.

Table 4. Mutambara crop water requirements, with project cropping intensity: 100 percent summer; 85 percent winter.

Notes	Item		July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
1	E pan Peak, mm		124	170	235	274	231	204	203	159	176	170	128	104
	E pan Mean, mm		113	156	218	250	209	173	179	142	157	151	116	96
2	Rain N80%, mm					1	37	60	61	40	21	5		
	Rain,mean, mm					26	75	134	154	116	78	22		
	Crop	percent	Mean month factor, Et/Eo											
3 .	Short Maize	75				PI	0.34	0.92	0.98	0.71				
	Long Maize	15				PI	0.33	0.87	1.00	0.90	0.40			
	Cotton	10					PI	0.55	0.87	0.96	0.90	0.13		
	Wheat	51	0.83	0.36								PI	0.44	0.82
	Beans	8.5	0.90	0.38									0.17	0.60
	Peas	8.5	0.90	0.90									0.07	0.66
	Tomato	17	0.70	0.58								PI	0.53	0.69
	Percent land use		85	85		90	100	100	100	100	25	78	85	85
	Et/Eo crop pattern		0.695	0.391			0.305	0.876	0.972	0.764	0.150	0.033	0.335	0.650
	mm per hectare cropped													
	pre-irrigation					43.5	53.5					52	13	
4	adjusted rain, N80%						37	60	61	40	3	4		
5	Nett CWR Peak Et crop		86	65		44	87	119	136	81	23	54	56	68
	Nett CWR Mean Et crop		79	61		44	80	92	113	68	21	53	52	62
6	Nett IWR Peak Et crop		163	125		82	164	224	257	154	44	101	105	128
	Nett IWR Mean Et crop		148	115		82	151	173	213	129	39	100	98	118

Notes :
1 Screened Class A pan evaporation, Grand Reef (22 years)
Peak is Normal 80 percent probability of non-exceedance.
2 N80 percent, Normal 80 percent probability of exceedance for Mutambara Mission (60 years)
3 PI = pre-irrigation
4 Rainfall adjusted for proportion of hectares cropped and period under crop.
5 Crop Water Requirement, nett of rainfall, Peak and Mean Evapotranspiration
6 Irrigation Water Requirement at 53 percent overall efficiency

Source: GKW/HTS/BCHOD

The nomogram of Figure 5 (Ref. 6) allows the power requirements for irrigation pumping to be estimated, depending on a variety of factors. In the peak month in the area of interest, the typical (average) daily requirement will be 220/31 mm; i.e., approximately 7 mm. Given a head range of 5-15 m and assuming (say) 8 hours pumping per day with a 60 percent efficient pump, gives a theoretical power requirement in the range of 2-6 kW per 10 ha. This implies the use of engines of typically 5-10 kW for a 10 ha block. In the one small scheme visited, Rupungwana, a slightly larger engine than this was in use, implying probably a marginally higher water demand (Rupungwana is further down the river and hotter and drier) combined more likely with various inefficiencies. For example, a government irrigation engineer mentioned that most irrigation water demand calculations assume water application efficiencies of about 60 percent but that it is common to find in reality and efficiency in the order of 30 percent is being achieved (due to bad system management largely). However, one effect of the use of a seemingly larger than necessary engine in such circumstances is that the larger engine is likely to last longer and perform more reliably.

4.3 Relative Costs of Different Pumping Options

This is a somewhat academic question, since in most cases, the choice is dictated by the policy of using gravity schemes where possible and otherwise mains electricity. In any case, the favored options appear significantly less expensive than any others, which of course is one reason why they are preferred.

The base-line for comparison is gravity irrigation schemes, which currently cost Z$8,000 to $12,000 per hectare in capital investment for government sponsored schemes.

Incidentally, farmers abstracting water under government schemes typically pay at the rates shown in Table 5 (Ref. 5).

Table 5. Irrigation water tariffs charged by government.

Tariff	All Year Z$/ha	Summer Only Z$/ha	Winter Only Z$/ha
A	145	90	55
B	72	45	30
C	30	30	30

A = water supply assured; B = periodic shortages experienced; C = sand abstraction schemes or summer/winter only schemes.

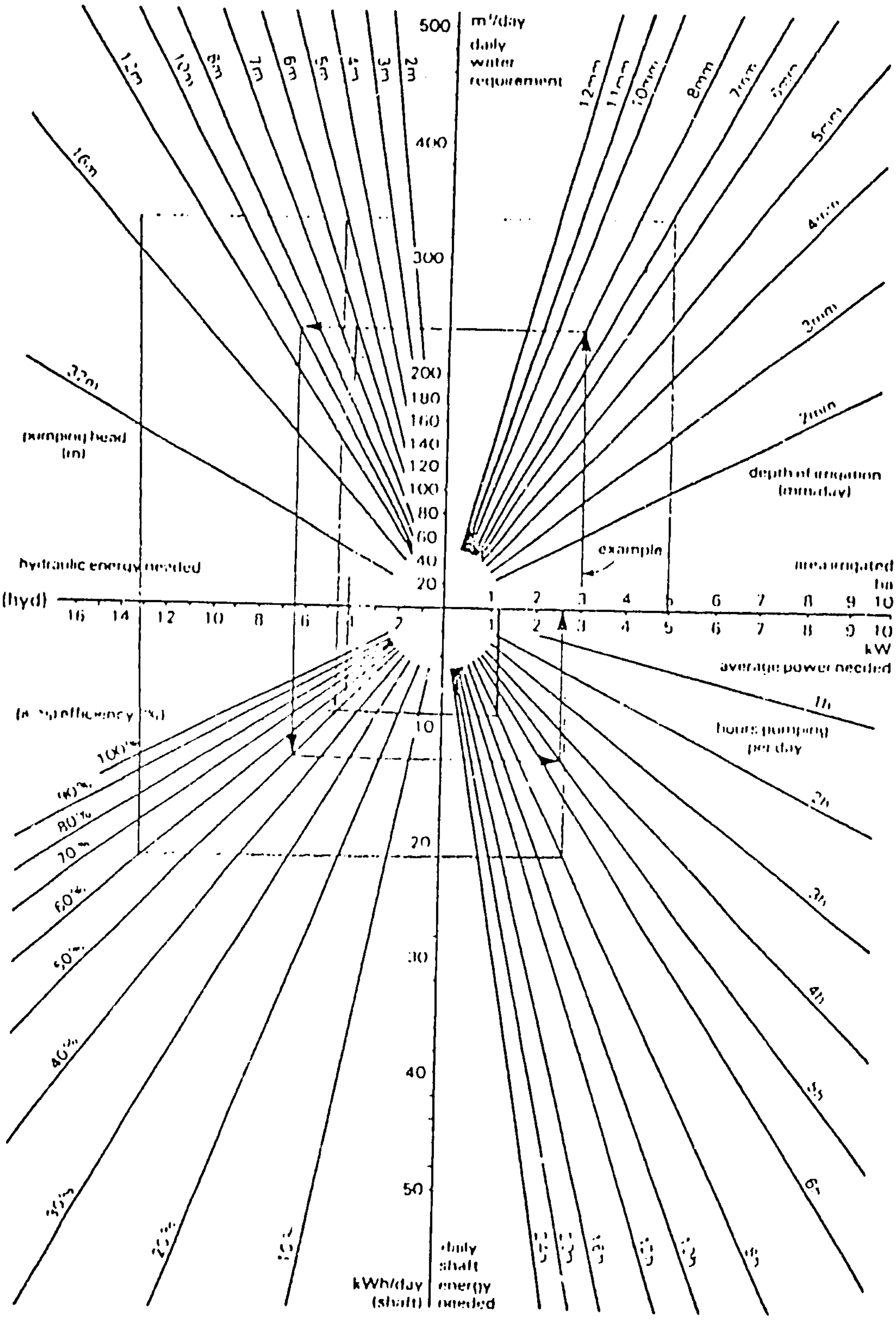

Figure 5. Nomogram for calculating power needs for a given area, depth or irrigation and head.

A useful, almost definitive, reference on relative costs of different water lifting systems is by K.M. Elliott (Ref. 7). This compares all conceivable irrigation water abstraction techniques for small-scale landholdings in Zimbabwe, for heads of 3, 10, 30 and 60 m and pumping rates from zero to 1,000 m^3/day (the upper limit would cover approximately 100 ha to 10 mm, so is relevant to quite large landholdings). The results of this analysis for 10 m and 30 m heads are given in Figure 6. Although one or two assumptions in the analysis behind these curves might be open to question, the analysis is basically sound, so there is no doubt that the ranking obtained is substantially correct. Although the absolute values may have changed slightly since this paper was produced in 1983, the changes are unlikely to have changed the relative costs significantly. For example, the price of diesel fuel was taken as Z$0.52/litre, where in fact it is now Z$0.62/litre. However, such changes are much too small to have any significant effect on altering the ranking of the options.

Elliott does show that handpump, ox and windmill irrigation are cheaper than electric, diesel or solar for a pumping rate of 10 m^3/day at a head of 3 m, but such duties would only occur for informal sector vegetable cultivation using water from dambos or vleis (which is not strictly a legal activity as water abstraction rights to do this are rarely if ever granted). His general conclusion was that neither windmills nor solar pumps could be viable for irrigation purposes in Zimbabwe in the short to medium term. He advocated the development of ox and handpumps more suitable for irrigation as being appropriate for use by small farmers currently relying on rainfed cultivation, and that mains electricity or diesels make most sense for larger schemes such as those managed by cooperatives.

There seems little point in reproducing a similarly rigorous updated version of Elliott's calculations, since there is no reason to believe significantly different findings would appear.

5. OPERATIONAL CONSIDERATIONS

5.1 Maintenance

Apart from difficulties in obtaining spare parts caused mainly by reductions in foreign currency allocations, there is a major problem in the government sector in finding and retaining competent mechanics and technicians. Well-experienced and capable staff are rare anyway, but tend to be lured into the private sector which offers better pay and conditions. Hence, there is a small corps of seemingly highly capable and experienced technical managers who are well aware of their problems and the solutions, but incapable of doing much about it due to lack of middle-level people to deploy to cope with breakdowns and regular maintenance.

The author understood that the situation is now so difficult that any planned maintenance of pumping systems in Manicaland, for example, has to "go by the board" as the limited technical resources are applied to coping with emergencies.

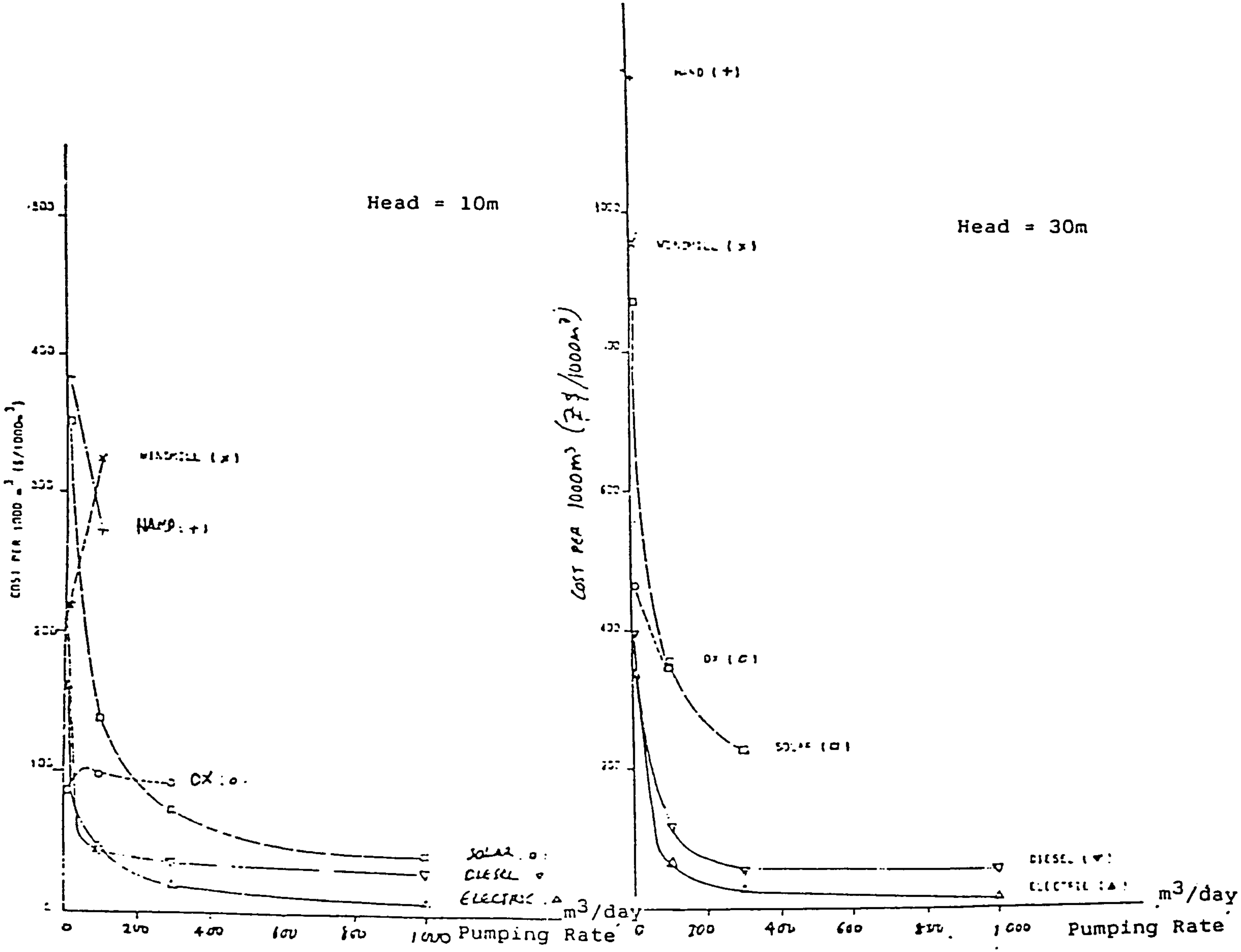

Figure 6. Variation of cost with pumping rate.

As a result, five of the six i.c. engine pumps at Nyanyadzi, for example, were unservicable at the time of the author's visit. Four had been out of use for many months. Fortunately, the gravity part of the system was sufficient to keep the scheme functioning and the engine pumps are shortly due to be replaced by electric pumps as mains power has just been connected. However, foreign currency problems have delayed the procurement of various components for the new electric pump house. This is believed to be a typical situation in Zimbabwe today.

It has to be said, however, that the standards in Zimbabwe are still very high for the region and the critical reactions were gained from officials who are used to maintaining high standards. Compared with many other parts of Africa, the levels of skill and organization are exceptionally high and government utilities generally function very effectively. For example, mains electricity failures are rare, the telephone network is one of the best and most comprehensive the author has experienced in Africa, maintenance crews working for the Electricity Supply Commission, the Posts and Telecommunications, and the Ministry of Energy and Water Supply were seen in a number of remote areas obviously performing their duties. At the Rupungwana irrigation project, the pump on the single diesel engine had just been changed by a crew from the Ministry of Energy and Water Resources & Development because the previous pump was not performing well; they were still on site during the author's visit and gave a competent impression.

In summary, therefore, the operational problems look set to increase in the face of shortages of equipment, spares and manpower, but any decline is from what is by most standards quite a high level. Hence, the preference for introducing mains electrification and/or gravity schemes wherever possible to reduce the pressure on the already stretched resources available.

6. POTENTIAL FOR USE OF INNOVATIVE ENERGY/PUMPING SYSTEMS

As has been already explained, there is little or no potential for introducing innovative pumping systems in Zimbabwe, at least in the existing public or private sector scales of conventional irrigation.

There may be some potential in the informal small-scale sector, to help poor farmers move from subsistence into cash cropping and to help small-scale production of vegetables in regions close to urban markets. However, there are problems in both these areas in relation to water abstraction rights, without which any such activities are potentially or actually illegal.

Assuming such problems can be bypassed or overcome, then the technical options that appear most promising in areas where mains electricity is not available are either animal-powered devices or manually operated devices (providing these are for low lifts < 5 m) and small land areas (<1 ha). Some studies of these options have been carried out by both the University of Harare and the Institute of Agricultural Engineering of Zimbabwe, but no appropriate equipment is immediately available for pilot projects, let alone for general use by individual farmers.

Although there seems little immediate prospect for using renewable energy to pump irrigation water, there are prospects for using irrigation water to generate electricity. The Ministry of Energy and Water Resources and Development has completed a preliminary feasibility study (Ref. 8) to look at opportunities to introduce small-scale (mini or micro) hydro-electric systems. Apart from various opportunities for small-scale stand-alone systems, the study identified the possibility of using existing dams and gravity irrigation systems as sources of hydro-electricity. Table 6, taken from that study, indicates 12 possible dams with estimates of their power generation capability. Although Zimbabwe is well-endowed already with electricity generation capacity, there is serious high level interest in the Ministry in utilizing these sources if it can be shown that the investment needed will yield power at a competitive price. A preliminary estimate in Ref. 8 indicates that any installation of generating equipment would need to cost less than Z$1,000/kW to generate electricity competitively with Kariba. This is just about possible and perhaps makes it worth initiating a more detailed and definitive study.

Table 6. Energy potential of existing dams.

Dam	MAR (0^6m^3)	Capacity (0^6m^3)	Yield (0^6m^3)	Head (m)	Annual Energy (GWS)	Mean Power (UN)
1-Bangala	723	130	455	40.0	37.2	4300
2-Kyle	494	1425	272	40.8	23.6	2635
3-Ruti	100	140	86	30.6	5.0	570
4-Manjirenji	129	285	761	29.3	4.5	525
5-Mazwikadei	162	345	80%x99.7	47.0	4.3	490
6-Manyuchi	138	300	59.0	40.0	3.6	410
7-Sebakwe	183	269	62.2	27.0	2.6	290
8-Palawan	67	74	30.1	38.0	2.4	275
9-Siya	44	108	26.4	42.9	2.4	275
10-Lesapi	83	88	31.5	36.0	2.4	275
11-Esquilingwe	833	12	483	2.0	2.0	230
12-Mazoe	60	35	19	30.5	1.2	140

Zimbabwe would require specialized technical assistance with such a study, and the author understood that any offers of assistance in this area would be well received. For completeness, any such study would require an investigation into small stand-alone systems for use in the highlands in off-the-grid applications, too.

There may also be opportunities to use turbine pumps (i.e., small hydro-turbines directly driving centrifugal pumps; purpose designed turbine-pumps are so far only manufactured in the Peoples Republic of China, but they can also be improvised by coupling a small turbine via a standard industrial transmission (such as vee belts) to a standard centrifugal pump). Such systems would possibly enhance existing gravity schemes by utilizing canal drops or diversion drops to power such turbine pumps and hence to extend the command area accessible for the scheme. It is likely that a number of schemes could be extended in this way, but investigations would be needed to identify specific possibilities.

It is also worth mentioning that although solar and wind power do not seem appropriate in the irrigation sector, there are significant and technically mature activities to develop and market solar and wind-powered equipment from the industrial sector of Zimbabwe. The country already has two established farm windpump manufacturers (Stewart & Llyods and Sheet Metal Kraft) and one company is gearing up to assemble photovoltaic modules (importing the wafers) (WS & G Hi-Tech). This latter company has already sold and installed over 200 solar PV systems, most of which are for lighting or telecommunications. They have also developed a solar pump (aimed at borehold water-supply pumping for human or livestock drinking water). This uses a locally manufactured progressing cavity pump, imported modules (at present), and their own design of electronic controller. Approximately 12 of these systems have so far been sold and installed. It seems probable that solar pumps for water supplies would be economically viable in areas of Zimbabwe away from the grid. Solar photovoltaic power is being quite extensively used by the Posts and Telecommunications in Zimbabwe for powering repeaters and boosters in the rural telephone network.

Certainly, windpumps are viable for such purposes, despite a marginal wind regime. However, sales of windpumps are modest (probably a few dozen per annum). The most likely area to use them would be the southwest (Matabeleland South) where the country is flat and open and windspeeds are probably marginally higher. Windpumps used to be used on the Botswana section of what was Rhodesia Railways to pump water into raised steel storage tanks for the steam locomotives that used to run on that line until the early 1970s. If they could be relied on for that duty they could no doubt equally be relied on for drinking water which is needed generally in much smaller quantities.

As previously mentioned, biomass is used already in Zimbabwe on a large scale in connection with the sugar industry, which is energy self-sufficient using bagasse-fueled steam generating plants and which also produces ethanol for blending with gasoline sold nationwide.

No doubt there is also considerable potential for using biomass fuels for small-scale pumping and other applications of that kind in rural Zimbabwe, but as yet no appropriate equipment is available in the country. There are large volumes of agricultural residues, especially in association with irrigated agriculture, which could be used as fuel. The most likely technologies would be small steam or stirling engines, biogas part-fueled diesel engines, possibly producer gas with spark ignition engines, etc. A major investigation would be needed to assess the potential for these technologies and to see whether there are any sufficiently promising possibilities to justify setting up specialized pilot demonstration and evaluation projects. A problem is that most of these technologies remain immature and as already explained, there are problems in maintaining engine powered equipment in the field in Zimbabwe anyway due to shortage of skilled manpower.

7. CONCLUSIONS AND RECOMMENDATIONS

There are no obvious applications for innovative water lifting or pumping in the existing public and private irrigation sectors. However, the following areas may be worth further investigation:

1. The generation of electricity by installing mini or micro hydro-electric systems in existing gravity irrigation schemes (perhaps combined with a broader study of the potential for mini or micro-hydro in Zimbabwe). Such a study would be most appropriately carried out in association with the Ministry of Energy and Water Resources and Development.

2. The development of animal/human powered, very small-scale water lifting devices that might be eventually manufactured and widely disseminated for the informal small-scale farming sector to reduce dependence of small farmers on rain. The most likely counterpart organizations for such an initiative would be the Institute for Agricultural Engineering which is already active in this field.

3. A study of the potential for using biomass fuels (particularly agricultural residues) for energizing small-scale irrigation systems, with a view to identifying the most promising avenues for further study and development.

4. Technical and financial support to push the emerging solar photovoltaic industry may be justifiable, but would need further investigation to find specifically what form such support should best take. This would not be related to irrigation pumping but could well involve water supply systems for village use.

8. REFERENCES

1. "A Review of Some Energy/Economic Issues in Zimbabwe" by Ron D. White, consulting economist, Austin, Texas, 1987.

2. Personal communication with Peter de Villez, irrigation manager, Stewart & Lloyds Ltd., Harare.

3. Personal communication with Eng. T. Kabell, Ministry for Energy and Water Resources and Development, Harare.

4. "A Guide to Zimbabwe", Bonde & Rydstrom (eds.), Mambo Press, Gweru/Stockholm, 1986.

5. "Rehabilitation and Development of Small-Scale Irrigation Schemes on Communal Lands: Sector Review" Final Report, GKW Consultants, Hunting Technical Services and Brian Colguhoun O'Donnell and Partners, March 1985.

6. "Water Pumping Devices," by Peter Fraenkel, IT Publications, London, 1987.

7. "Water Pumping Costs for Small-Scale Irrigation in Zimbabwe," by K.M. Elliott, Inst. of Agricultural Engineering, Harare, Proc. Energy in Agriculture Symposium, Harare, May 1983.

8. "Feasibility Study on Mini-Hydro Power Development in Zimbabwe: Initial Report" Designs Divn., Dept. of Water Resources, Ministry of Energy and Water Resources and Development, Harare, November 1986.

ANNEX 1

(S) ACTION AIF-4 INFO .MS DCM/LF

VZCZCSH0?4?
PP RUFHSJ
DF RUEHC #2992/01 3543723
ZNR UUUUU ZZH
P 2007197 DEC 8?
FM SECSTATE WASHDC
TO AMEMBASSY HARARE PRIORITY 1939?
BT
UNCLAS SECTION 01 OF 02 STATE 392992

AIDAC

E.O. 12356: N/A
TAGS: N/A
SUBJECT: ADDITION OF ENERGY EXPERTISE TO WMS II ZIMBABWE JOINT FIELD STUDY

REF: (A) STATE 384723, (B) STATE 326077

1. ENERGY IS AN IMPORTANT PART OF IRRIGATION DEVELOPMENT IN AFRICA. ST/AGR AND ST/EY HAVE AGREED TO EXAMINE ENERGY ISSUES RELATED TO IRRIGATION AS A COMPONENT OF THE WMS II AND ITS FOLLOW-ON PROJECT (ISMAR). COLLABORATION WITH THE MISSION IS IMPORTANT.

2. AS INDICATED IN REF A, THE FOLLOWING PROPOSED SCOPE OF WORK WILL ADD ENERGY EXPERTISE TO THE JOINT FIELD STUDY FOR ZIMBABWE. IT WILL BE SUPPORTED BY THE ST/EY BUY-IN TO WMS II. THIS SOW HAS BEEN DISCUSSED WITH RICHARD MCCONNEN, EXECUTIVE DIRECTOR FOR THE WMS II PROJECT AND A MEMBER OF THE TEAM. MCCONNEN CONCURS THAT THE ADDITIONAL EXPERTISE WILL CONTRIBUTE SIGNIFICANTLY TO ACHIEVING THE PROGRAM'S OBJECTIVES.

A. PURPOSE: THIS ASSISTANCE WILL ADD RESOURCES TO THE JOINT FIELD STUDY TEAM TO EXAMINE HOW ENERGY CONSIDERATIONS AFFECT IRRIGATED AGRICULTURAL DEVELOPMENT

AT FOUR REPRESENTATIVE PUMPING SITES, AND THE IRRIGATION SECTOR IN GENERAL.

B. BACKGROUND: IT IS IMPORTANT TO TAKE INTO ACCOUNT BROAD ENERGY CONSIDERATIONS, AS WELL AS THE MORE SPECIFIC ONES RELATED TO PUMPING REQUIREMENTS, CAPACITIES, EQUIPMENT SELECTION, ETC. THESE BROADER ISSUES INCLUDE CONSIDERATION OF THE TYPE OF ENERGY SYSTEMS TO BE EMPLOYED (DIESEL, ELECTRIC, ETC.), ACCESS TO THE SYSTEMS, FUEL SUPPLY, AND MAINTENANCE OF THE PUMPING SYSTEMS. THESE CONSIDERATIONS APPEAR TO BE PARTICULARLY CRITICAL WITHIN THE AFRICA CONTEXT, WHERE FUTURE IRRIGATION SYSTEMS WILL INCREASINGLY RELY ON PUMPED WATER RESOURCES.

C. SCOPE OF WORK: THE ENERGY SPECIALIST(S) WILL COMPLETE THE FOLLOWING TASKS AS PART OF THE JOINT FIELD

Cable sent

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STUDY EFFORT IN ZIMBABWE...:

(1) IDENTIFY EXISTING POWER SOURCES AND DELIVERY MECHANISMS USED BY FARMERS AT THE PROJECT SITES. DETERMINE THE ADEQUACY AND RELIABILITY OF FUEL SUPPLY, I.E. DOES THE LACK OF FUEL OR ELECTRICITY LIMIT CROP PRODUCTION.

(2) DETERMINE IRRIGATION PUMPING ENERGY REQUIREMENTS. INDICATE SEASONAL WATER REQUIREMENTS AND DISTINGUISH BETWEEN CROPS TOTALLY DEPENDENT ON PUMPED WATER AND THOSE FOR WHICH PUMPING IS USED TO SUPPLEMENT RAINFALL.

INFO N6606

DETERMINE THE EFFICIENCY OF PUMPING SYSTEMS. A RANGE OF PUMPING SYSTEM SIZES APPROPRIATE TO THE STUDY AREAS ARE TO BE EXAMINED (FOR EXAMPLE, 4 - 25 HORSEPOWER RANGE).

DETERMINE THE ACTUAL ENERGY COSTS FOR PUMPED WATER FROM THE SYSTEMS EXAMINED. EVALUATE HOW THESE COSTS AFFECT THE OVERALL ECONOMIC VIABILITY OF IRRIGATION SYSTEM.

(3) DETERMINE FREQUENCY OF PUMP SERVICE THROUGHOUT THE YEAR. INDICATE IF PUMP MOTORS ARE USED DURING THE NON-IRRIGATION SEASON, AND FOR WHAT. DESCRIBE THE SERVICE NETWORK FOR PUMP REPAIR AND EVALUATE ITS EFFECTIVENESS. DETERMINE HOW POWER UNITS AND PUMPS ARE MANAGED BY THE FARMERS.

(4) DESCRIBE EXISTING INNOVATIVE POWER SUPPLY SYSTEMS, SUCH AS USE OF A SMALL CENTRAL POWER SYSTEMS

TO PROVIDE WATER FOR NUMEROUS SMALL LAND HOLDINGS.

(5) ANALYZE POTENTIAL OPPORTUNITIES TO DETERMINE A LEAST-COST APPROACH FOR DELIVERING POWER TO THE FIELD SITES. OPTIONS MAY INCLUDE RURAL POWER (CENTRAL OR DECENTRALIZED SERVICE), DEMAND MANAGEMENT, MECHANICAL PUMPING, AND INSTITUTIONAL ARRANGEMENTS SUCH AS FARMER COOPERATIVES, ETC.

(6) DETERMINE THE POTENTIAL OF PRIVATE SECTOR INITIATIVES TO MEET POWER NEEDS, PARTICULARLY FOR SMALL POWER SYSTEMS (1 MW - 25.MW).

(7) IDENTIFY INTERRELATIONSHIPS BETWEEN POWER FOR WATER PUMPING AND OTHER RURAL DEVELOPMENT NEEDS SUCH AS AGROPROCESSING, COTTAGE INDUSTRIES, COMMUNITY DEVELOPMENT, AND EMPLOYMENT GENERATION.

(8) EXAMINE DEVELOPMENT PLANS FOR IRRIGATION IN ZIMBABWE. EVALUATE THESE PLANS BY ACTIVITY AND LOCATION, AND DETERMINE THEIR POTENTIAL IMPACT ON POWER

IIPANT.

THE CONSULTANT(S) IN ADDITION TO INTEGRATING HIS FINDINGS INTO THE TEAM'S REPORT WILL ALSO REPORT HIS FINDINGS TO ST/EY IN DRAFT FORM WITHIN 10 DAYS OF THE COMPLETION OF THE FIELD TRIP. BASED ON ST/EY'S COMMENT, THE CONSULTANT(S) WILL SUBMIT 3 COPIES OF THE FINAL REPORT TO ST/EY WITHIN 21 DAYS. ST/EY WILL TRANSMIT A COPY OF THE REPORT TO THE MISSION AND TO WMS II. FIELD WORK SHOULD BE DOCUMENTED WITH SLIDES.

D. EXPERTISE AND SKILLS: THE CONSULTANT(S) SHOULD HOLD AN ADVANCED DEGREE IN ECONOMICS, ENGINEERING ECONOMICS OR THE EQUIVALENT, AND HAVE EXTENSIVE FIELD EXPERIENCE IN: (1) ANALYZING TECHNICAL ASPECTS OF ENERGY TECHNOLOGIES, ENERGY SYSTEMS AND AGRICULTURAL SYSTEMS; (2) ASSESSING ENERGY-PUMPING RELATIONSHIPS.

E. RECOMMENDED CANDIDATES:

1. ST/EY SENT MCCONNEN RESUMES OF CANDIDATES. MCCONNEN'S FIRST CHOICE IS PETER FRAENKEL WHO HAS AN ENGINEERING BACKGROUND AND IS CURRENTLY ASSOCIATED WITH IT POWER, INC. FRAENKEL'S ENGINEERING EXPERTISE WOULD ENHANCE THE SKILLS AND CAPABILITIES OF THE TEAM.

FRAENKEL IS A MECHANICAL ENGINEER WITH CONSIDERABLE EXPERIENCE WITH PUMPING AND POWER SYSTEMS IN DEVELOPING COUNTRIES. HE RECENTLY HAD A BOOK PUBLISHED BY FAO ON WATER PUMPING DEVICES. HE IS ALSO THE AUTHOR OF "THE POWER GUIDE: A CATALOGUE FOR SMALL-SCALE POWER EQUIPMENT."

FRAENKEL CAN PARTICIPATE WITH THE WMS II TEAM DURING THE ENTIRE STAY AND UNDERTAKE FIELD TESTING. HE WOULD BE RESPONSIBLE FOR ITEMS 1-4 OF THE SOW.

2. ST/EY AND AFR/TR/ARD/PA STRONGLY RECOMMEND AN ADDITIONAL CANDIDATE WHOSE ROLE WOULD BE TO EXAMINE BROADER ISSUES RELATED TO IRRIGATION AS OUTLINED IN ITEMS 5-8 OF THE SOW.

THE CANDIDATE, RON WHITE, HAS HAD EXTENSIVE EXPERIENCE INVOLVING NATURAL RESOURCE POLICY ISSUES (ENERGY, AGRICULTURE, AND ENVIRONMENT). HE SERVED AS A SENIOR ENERGY ECONOMIST FOR A.I.D. AND HAS PARTICIPATED IN NUMEROUS EVALUATIONS OF AID PROJECTS, INCLUDING THE RENEWABLE ENERGY EVALUATION EFFORT SPONSORED BY THE AFRICA BUREAU IN THE MID-EIGHTIES. WHITE'S INVOLVEMENT WOULD BE A USEFUL CONTRIBUTION TO THE UPCOMING BOTSWANA CONFERENCE (REFTEL B) WHERE COUNTRY EXPERIENCES IN WATER PUMPING AND ENERGY ISSUES WILL BE SHARED WITH ADOS AND OTHER PARTIES. WHITE'S WORK WOULD TAKE APPROXIMATELY TWO WEEKS AND HIS EXAMINATION OF MACRO ISSUES MIGHT NOT REQUIRE HIS INVOLVEMENT IN FIELD WORK DURING THE ENTIRE TWO WEEK PERIOD.

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ANNEX 2
MEMBERS OF MISSION & CONTACTS VISITED

1. MEMBERS OF MISSION

US Agricultural Team

Terry Podmore	-	Team Leader/Irrigation Engineer
Tom Flack	-	Agronomist
Dick McConnen	-	Economist
Robby Laitos	-	Sociologist
Max Donkor	-	Irrigation Engineer

Zimbabwe Team

Soloman Tembo	-	Local Coordinator/Ag. Engineer
Pangirai Tongoona	-	Agronomist
Ransam Mariga	-	Economist
Seymour Gimani	-	Irrigation Engineer
Isaac Moyo	-	Irrigation Engineer
Aiden Senzanje	-	Irrigation Engineer

Energy/Planning

Ron D. White	-	Economist
Peter L. Fraenkel	-	Energy Specialist/Mechanical Engineer

2. CONTACTS VISITED BY FRAENKEL

Alison Herricks, Director, USAID/Harare
Eric Witt, Agricultural Officer, USAID/Harare
Joshua Mushauri, Assistant Economist, USAID/Harare
David Hancock, Development Technical Center University, Harare
Gudula Kaeser-Hancock, Development Technical Center University
Soloman Tembo, Ag. Faculty, University of Harare
T.C. Kabell, Head, Design Dept., Ministry of Energy, Water and Development (EWD)
J.R. Holland, Mechanical Engineer, Ministry of EWD.
Mike Leonard, Provincial Agricultural Officer, Manicaland
Pat Horsefield, Irrigation Officer, Manicaland
Geoff White, Acting Provincial Water Engineer, Manicaland
Fransesco Manza, ARDA Provincial Planning Unit, Mutare
John Harahwa, AGRITEX Ext. Officer, Nyanyadzi
M. Hlaruka, Ministry Energy, Water and Development maintenance team
Mike Mollett, Managing Director, WS&G Hi-Tech Ltd., Harare
Keith Elliott, Director, Inst. of Agr. Engineering, Harare
Peter Rijk, Coordinator of GTZ Projects at Inst. Ag. Eng.
Borre Hover, Engineer working on solar pump at Inst. Ag. Engr.
Peter C. de Villez, Irrigation Manager, Stewards + Lloyds
J.E. Stevens, Solar Energy Soc. of Zim., former Chief Met. Officer

ANNEX 3

SCHEME	:NYANYADZI			Number	:	11
	Province	:	Manicaland	Communal Area	:	Muwusha
	District Council	:	Mabvazuva	Map Reference	:	VP 3814
	Gazetted area	ha	2980	Developed area	ha	414***
PHYSICAL ENVIRONMENT	Natural Region	:	V	Altitude	masl	570
	Annual Rainfall	mm	489	Coefficient of variation	%	35
	Annual Evaporation	mm	2010	Peak daily evaporation		
				November	mm	7.3
				April	mm	5.2
	Soil Texture: Surface	:	Mod. coarse-mod.fine	Soil Texture: Subsurface	:	Medium
HISTORY	Year of construction	:	1933	Year of reconstruction	:	1957 (2nd water right)
	Year of extension	:	1957 & subsequently	Present status	:	Operational
	Operated by	:	DERUDE			
WATER SOURCE	Abstraction method	:	Gravity, 6 pumps (D)	Water source	:	Odzi(P)/Nyanyadzi(G
	Water right	Mm3/yr	3903+1098	Water right	l/s	85+283+400
				Security of supply	:	Moderate
SCHEME INFRA-STRUCTURE	Headworks	:	Weir pumphouse	Electricity	:	Soon
	Conveyance to field edge	km	12,5 (unlined)	Telephone	:	Cashel 02012
	Night storage	:	Yes (3 days)	Storage	:	Yes
	Distribution system	km	62 (lined)			
IRRIGATED AGRICULTURE	Main crops: Summer	:	Maize (73%), cotton			
	Main crops: Winter	:	Beans (73%), wheat, tomatoes			
	Average Cropping intensity 1974-77 S/W	%	97/138	1981-84 S/W	%	84/81
	Irrigation system	:	Border bed			
	Present irrigation interval	days	12-21			
SOCIO-ECONOMIC DATA	No of tenants (1984)	:	451			
	Plot size distribution	:				
	<= 0.1 ha	%	6	0.1 to 0.4	%	23
	0.4 to 1.0	%	36	> 1.0 ha	%	35
	Modal plot size	ha	0,8/1,6			
	Average family size (1982)	:	10.8	Adults per holding (1982)	:	3.6
	Male:female ratio (1982)	:	78:100	Population density (1982)	/km2	29.2
	Percent of tenants owning oxen (1982)	%	72	Percent of tenants owning donkeys (1982)	%	
	Nearest Town or growth point	:	Birchenough Bridge	Distance	km	28
	Nearest District or Rural Service Centre	:	Nyanyadzi*	Distance	km	1
	Cooperative	:				
OPERATION AND MAINTENANCE	No of staff paid by DERUDE	:	57**	AGRITEX	:	5
	by MEWRD	:	2	COMMUNITY	:	0
	Maintenance Fee Grade	:	A	Committee Rating by DERUDE 1984	:	Poor
	Percent of Fees collected 1983/84	%	62	Replied to letter	:	Yes

NOTES :Scheme studied by M. Rukuni (1984).
Site of investigations by Hydraulics Research. Has a meteorogical station.
Serious illegal abstraction taking place. Seepage and sodic subsoil problems.
Frequent pump failures. ** Committee thinks it could be operated after rehabilitation by 1 supervisor, 8 workers, and communal labour.

SCHEME	:TAWONA			Number	:	12
	Province	:	Manicaland	Communal Area	:	Mutema
	District Council	:	Gazaland	Map Reference	:	VN 3173
	Gazetted area	ha	320	Developed area	ha	151*
PHYSICAL ENVIRONMENT	Natural Region	:	V	Altitude	masl	475
	Annual Rainfall	mm	408	Coefficient of variation	%	33
	Annual Evaporation	mm	2080	Peak daily evaporation		
				November	mm	7.3
				April	mm	5.1
	Soil Texture: Surface	:	Mod. coarse & Medium	Soil Texture: Subsurface	:	Moderate fine
HISTORY	Year of construction	:	1954	Year of reconstruction	:	1970
	Year of extension	:		Present status	:	Operational
	Operated by	:	DERUDE			
WATER SOURCE	Abstraction method	:	3 Pumps (E)	Water source	:	Sabi River
	Water right	No	4381+ 3095	Water right	l/s	25+85
		m3/yr		Security of supply	:	Moderate
SCHEME INFRA-STRUCTURE	Headworks	:	Pumphouse	Electricity	:	Yes
	Conveyance to field edge	km	4.5 (lined)	Telephone	:	-
	Night storage	:	No	Storage	:	With Mutema
	Distribution system	km	19 (lined)			
IRRIGATED AGRICULTURE	Main crops: Summer	:	Maize (81%), cotton			
	Main crops: Winter	:	Beans (77%), tomatoes, wheat			
	Average Cropping intensity					
	1974-77 S/W	%	97/97	1981-84 S/W	%	98/88
	Irrigation system	:	Border bed			
	Present irrigation interval	days	12			
SOCIO-ECONOMIC DATA	No of tenants (1984)	:	213			
	Plot size distribution	:				
	<= 0.1 ha	%	0	0.1 to 0.4	%	23
	0.4 to 1.0	%	77	> 1.0 ha	%	0
	Modal plot size	ha	0.8			
	Average family size (1982)	:	9.6	Adults per holding (1982)	:	3.5
	Male:female ratio (1982)	:	77:100	Population density (1982)	/km2	49.2
	Percent of tenants owning oxen (1982)	%	77	Percent of tenants owning donkeys (1982)	%	0
	Nearest Town or growth point	:	Birchenough Bridge	Distance	km	35
	Nearest District or Rural Service Centre	:		Distance	km	
	Cooperative	:	Yes but not functioning well			
OPERATION AND MAINTENANCE	No of staff paid by DERUDE	:	55	AGRITEX	:	7
	by MEWRD	:	2	COMMUNITY	:	
	Maintenance Fee Grade	:	A	Committee Rating by DERUDE 1984	:	Average, fair
	Percent of Fees collected 1983/84	%	100	Replied to letter	:	Yes

NOTES :* A 71 ha extension is being considered by DERUDE.

SCHEME	:MUTEMA			Number	:	8
	Province	:	Manicaland	Communal Area	:	Mutema
	District Council	:	Gazaland	Map Reference	:	VN 3172
	Gazetted area	ha	520	Developed area	ha	237 (183 sprinkler)
PHYSICAL ENVIRONMENT	Natural Region	:	V	Altitude	masl	475
	Annual Rainfall	mm	409	Coefficient of variation	%	33
	Annual Evaporation	mm	2080	Peak daily evaporation		
				November	mm	7.3
				April	mm	5.1
	Soil Texture: Surface	:	Medium	Soil Texture: Subsurface	:	Moderate fine
HISTORY	Year of construction	:	1932	Year of reconstruction	:	Sprinkler sect. 1973
	Year of extension	:	1952	Present status	:	Operational
	Operated by	:	DERUDE			
WATER SOURCE	Abstraction method	:	Pump(E) 4 boreholes and Gravity*	Water source	:	Groundwater & Tang. River
	Water right	No m3/yr	745+92	Water right	l/s	71+283
				Security of supply	:	Moderate surface Good groundwater
SCHEME INFRA-STRUCTURE	Headworks	:	4 pumphouses	Electricity	:	Yes
	Conveyance to field edge	km		Telephone	:	Chipinge 30419
	Night storage	:	0+4,5***	Storage	:	Yes, plus workshop
	Distribution system	km	14 (pipes) + 7			
IRRIGATED AGRICULTURE	Main crops: Summer	:	Maize (83%), cotton, groundnuts			
	Main crops: Winter	:	Beans (58%), tomatoes, wheat			
	Average Cropping intensity					
	1974-77 S/W	%	98/99	1981-84 S/W	%	100/99
	Irrigation system	:	Border bed (54 ha), sprinkler (183 ha)			
	Present irrigation interval	days	14-20			
SOCIO-ECONOMIC DATA	No of tenants (1984)	:	347			
	Plot size distribution	:				
	<= 0.1 ha	%	0	0.1 to 0.4	%	26
	0.4 to 1.0	%	74	> 1.0 ha	%	0.3
	Modal plot size	ha	0.45			
	Average family size (1982)	:	7.3	Adults per holding (1982)	:	2.7
	Male:female ratio (1982)	:	68:100	Population density (1982)	/km2	49.2
	Percent of tenants owning oxen (1982)	%	48	Percent of tenants owning donkeys (1982)	%	0
	Nearest Town or growth point	:	Chipinge	Distance	km	45
	Nearest District or Rural Service Centre	:	Tanganda Halt RSC	Distance	km	8
	Cooperative	:	Yes, but not functioning well			
OPERATION AND MAINTENANCE	No of staff paid by DERUDE	:	55**	AGRITEX	:	7*
	by MEWRD	:	4	COMMUNITY	:	0
	Maintenance Fee Grade	:	A	Committee Rating by DERUDE 1984	:	Average, fair
	Percent of Fees collected 1983/84	%	74	Replied to letter	:	Yes

NOTES :* Gravity, weir from Tanganda River.
** This staff operates also at Tawona.
*** 0 from groundwater, 4.5 from Tanganda River.
Scheme visited by GKW/HTS/BCHOD.

SCHEME	:RUPANGWANA			Number	:	30
	Province	:	Masvingo	Communal Area	:	Sangwe
	District Council	:	Gaza Komani	Map Reference	:	VM 1477
	Gazetted area	ha		Developed area	ha	10*
PHYSICAL ENVIRONMENT	Natural Region	:	V	Altitude	masl	350
	Annual Rainfall	mm	463	Coefficient of variation	%	36
	Annual Evaporation	mm	2130	Peak daily evaporation		
				November	mm	7.8
				April	mm	4.8
	Soil Texture: Surface	:	Variable alluvium	Soil Texture: Subsurface	:	Variable alluvium
HISTORY	Year of construction	:	1979	Year of reconstruction	:	
	Year of extension	:		Present status	:	Operational
	Operated by	:	DERUDE			
WATER SOURCE	Abstraction method	:	1 Pump (D)	Water source	:	Sabi River
	Water right	No	12226	Water right	l/s	40
		m3/yr		Security of supply	:	Moderate (pump)
SCHEME INFRA-STRUCTURE	Headworks	:	Pumphouse (pool)	Electricity	:	No
	Conveyance to field edge	km	0.5 (pipe + canal)	Telephone	:	No
	Night storage	:	No	Storage	:	No
	Distribution system	km	1.5			
IRRIGATED AGRICULTURE	Main crops: Summer	:	Green maize (89%), grain maize			
	Main crops: Winter	:	Beans (58%), tomatoes (25%), vegetables			
	Average Cropping intensity					
	1974-77 S/W	%		1981-84 S/W	%	71/47**
	Irrigation system	:	Furrow			
	Present irrigation interval	days	10-12			
SOCIO-ECONOMIC DATA	No of tenants (1984)	:	39*			
	Plot size distribution	:	*			
	<= 0.1 ha	%	59	0.1 to 0.4	%	41
	0.4 to 1.0	%	0	> 1.0 ha	%	0
	Modal plot size	ha	0.1*			
	Average family size (1982)	:	10.8	Adults per holding (1982)	:	4.6
	Male:female ratio (1982)	:	107:100	Population density (1982)	/km2	27.4
	Percent of tenants owning oxen (1982)	%	38	Percent of tenants owning donkeys (1982)	%	0
	Nearest Town or growth point	:	Chiredzi	Distance	km	52
	Nearest District or Rural Service Centre	:	Tshovane	Distance	km	1
	Cooperative	:				
OPERATION AND MAINTENANCE	No of staff paid by DERUDE	:	2	AGRITEX	:	1
	by MEWRD	:	1	COMMUNITY	:	0
	Maintenance Fee Grade	:	B	Committee Rating by DERUDE 1984	:	Good to very good
	Percent of Fees collected 1983/84	%	100	Replied to letter	:	Yes

NOTES :Pump failures and the absence of a night storage dam cause difficulties.
Scheme studied by Munzwa (1981). Rehabilitation and extension proposed by Masvingo PPU (1983).
* Pump output reduced from 40 l/s to 20 l/s to improve reliability in 1980 so irrigable area limited to 6.3 ha.
** of 6.3 ha.

APPENDIX C

A REVIEW OF SOME ENERGY/ECONOMIC ISSUES IN ZIMBABWE

Prepared for: U. S. Agency for International Development
Bureau for Science and Technology
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Energy/Economic Issues in Zimbabwe

PREFACE

Within US A. I. D., the Bureau for Science and Technology's Office of Energy has been concerned for some time with the energy implications of irrigation in Africa. An outline of this concern along with an overview of the cooperation with other A. I. D. offices and missions is set out in State 392992 of 20 Dec 1986. This report is a part of the work described in the cable.

A draft version of this report was provided to the Government of Zimbabwe, the US A. I. D. mission in Harare, the Bureau for Africa as well as other interested parties within US A. I. D./Washington, and other contractors working on irrigation projects including--most specifically--the participants in the Joint Field Workshop conducted in Zimbabwe as part of the Water Management Synthesis II Project. This report is being incorporated, as an appendix, into the report from the Joint Field Study.

This report is intended to be complementary to the Joint Field Study work. There are many perspectives on the energy/irrigation problem and better information and analysis are needed to clarify better courses of action. The energy/irrigation issues included in this report are general, rather than site-specific. The author did not accompany the team to the field to gather data on selected sites, but sought primarily to develop better information regarding the chief source of energy for pumping in Zimbabwe, electricity.

The author was in Zimbabwe from January 22 through February 8, 1987 at which time the exchange rate was $1.00 = Z$1.67.

CONTENTS

SUMMARY OF FINDINGS

Energy In Agriculture

1. While the statistics on cropped area in Zimbabwe show that communal agriculture is the dominant form, large scale commercial farms actually use more than ninety percent of each energy source.

2. Agricultural use is about five percent of all end use energy and between four and seven percent of all electricity.

3. While designs using gravity flow irrigation are naturally preferred, electricity is the chosen source of energy for pumping--based on both financial costs and reliability.

4. Electricity is now sold to farmers through a tariff which is characterized by declining block pricing, i. e., the average price per Kwh declines with greater use. The tariff is being revised, but the new structure and prices have not yet been made public. The declining block will likely end.

5. Due to drought, the historical pattern of electricity consumption by the farm sector has been quite erratic.

6. Pumping costs were compared for electric and diesel pump sets for a given load; electrically-powered pumping is cheaper by half for a large unit (113 kW).

Energy and Development

7. Irrigation costs have remained virtually constant as a proportion of a commercial farmer's variable costs over the last several years.

8. Rural electrification will not likely add loads of any great significance to the system in the near future, inspite of an agressive program of extending the grid.

9. Growth centers (areas to which power is being extended), are not being given further management in terms of ensuring that secondary development actually takes place.

10. One excellent example of capital-conserving energy investments is Triangle Estates which grows cane and produces sugar, ethanol, carbon dioxide, and generates power for its own use and sells to the grid as well.

11. Self-sufficiency in wheat is a national goal implying considerable use of irrigation, although there are no comprehensive estimates of the energy needed to achieve the goal.

12. Existing declining block rates may deter private investment in power production. That is, besides encouraging over-use of water and electricity and over-investment in energy generation and distribution facilities, rates not based on costs deter investments in energy efficient end-use equipment as well as cogeneration/small power production.

13. There are no specific programs or incentives to promote private or public cogeneration and/or small power production.

Least Cost Supply Strategy

14. The application of a least-cost approach to energy supply is quite complex in an economy undergoing such a fundamental transition as is being experienced in Zimbabwe. Nonetheless, the Government of Zimbabwe has in-place programs which if fully implemented should move irrigation investment toward the least-cost technology.

15. The loan fund which would supply capital to farmers for irrigation needs and other projects is a conceptually sound approach to making capital available. Adjustments in the structure of the program may be needed in order for it to achieve its full potential.

17. The Zimbabwe Electric Supply Authority (ZESA), does have a program which provides information to its customers regarding the sizing of electric-drive equipment, including irrigation equipment.

ENERGY FOR AGRICULTURE: Overview

It is useful to begin by examining the general categories of agricultural energy use by type of energy and by type of agricultural entity to develop a context for understanding the specific problems to be investigated. Agriculture in Zimbabwe can be categorized into seven sectors: communal farms, large-scale commercial farms, Resettlement Model A Farms, small scale commercial farms, small scale irrigation farms (Department of Rural Development and Agricultural and Rural Development Authority outgrowers), and cooperative farms including all cooperatives and Resettlement Model B farms. Table One below shows the cropped areas of each category along with the corresponding share of energy used by energy source.

TABLE ONE

Agricultural Area and Percentage Energy Use
by Sector and Energy Source

Sector	Area Cropped	Diesel Oil Gas	Coal	Electric	Wood	Total
Communal	2892.6	0.02				0.02
Lg. Scale Commercial	588.9	2.65	8.75	1.81	7.27	20.49
Resettlement-A	84.4	0.01				0.01
State Farms	16.1	0.07	0.02	0.10		0.19
Sm. Scale Commercial	67.2	0.01				0.01
Sm. State Farms	4.3	0.01				0.01
Cooperative Farms	22.6	0.02	0.02	0.02	0.04	0.10
Total	3676.1	2.78	8.79	1.94	7.32	20.83

n.b. area in 1000's HA; Energy in Petajoules.
(does not include animal energy)
Source: Beijer, 1985, p. 30 & 31.

From this it can be seen that the cropped area is dominated by communal and other non-commercial agriculture. Energy use, however, is another matter. Over ninety percent of each energy category is used by the Large Scale farms. Moreover, within the Large scale farms, coal and woodfuel dominate their energy use. On commercial farms, these fuels are used for curing tobacco, which is historically and currently important to Zimbabwe as an earner of foreign exchange. The coal, importantly, is domestically produced. In their study, the Beijer Institute concluded that taken as a whole commercial farms used 35 GJ per hectare, state farms 12 GJ per hectare, and cooperative farms used 4 GJ per hectare. These energy intensities vary according to crops grown and methods employed.

In 1982, agriculture used about 5.3 percent of all end use energy and about 4.0 percent of the electricity consumed in Zimbabwe according to Beijer data. Electric utility sales data from ZESA show somewhat more, 8.4 percent of sales in 1986. No explanation of the difference was available.

With respect to water pumping, including crop irrigation, there is no agreed upon set of figures estimating energy use at that sub-sector level. It is clear from all discussions held (with ZESA, various ministries, Agritex, etc.) that the preferred energy source (following gravity, of course) is electricity. It is used anytime it is available. Most Ministry projects use gravity. When diesel pumps are used, they are replaced with electric motors when power becomes available. Cost is invariably the main reason cited, followed very closely by reliability, as the rationale for choosing electricity. Obviously these two items are closely related.

Since electricity is the preferred means of pumping, it is important to examine the general question of the supply of and demand for electricity in Zimbabwe.

The Supply of Electricity

Organizational Structure

In 1985 the Parliament of Zimbabwe enacted legislation creating a single power authority for the nation, the Zimbabwe Electric Supply Authority (ZESA).

The pre-existing authority was known as the Electric Supply Commission (ESC) and it represents the core of ZESA, the other merged components being three municipal utilities.

Supply

The majority of the nation's energy is purchased from the Kariba hydroelectric project on the Zambezi River--a joint project with Zambia. The ESC/ZESA owns 401.5 MW of thermal generation, which burn domestically produced coal. In addition, energy is purchased from other sources, including private companies, as follows:

Source	Amount (kWh)
Hippo Valley Estates	(none-1985)
Triangle Estates	581,802
Electric Supply Commission, South Africa	10,194,542
Zambia Electric Supply Commission	589,895

Hippo Valley and Triangle Estates are sugarcane mills which are interconnected to ZESA and can sell to or buy from the grid. The line to Triangle will handle about two MW of about 24 MW at the mill and is really used in emergencies or during maintenance. In addition to these two non-utility firms which generate and sell to the grid, there are other industrial facilities within the country which generate electricity for all or part of their needs. While there is no published information on these plants, the range of firms involved includes a steel mill, a textile mill, and the above mentioned sugarcane estates.

Demand

In 1985 the peak demand occured in June and was 751.4 MW, an increase of 7.28 percent over the previous year. Sales have generally increased in recent years, but--importantly--not always. In fact, the pattern of growth and contraction is one of the most striking characteristics of the system. Since 1975, there have been four years in which total sales have decreased. Though no published analysis of this pattern was found, it is commonly explained as being related to the level of economic activity and, in turn, levels of rainfall and their effects on crop production. Indeed, if one examines the farming component of demand in comparison to the rest of the system demand, that can clearly be seen.

TABLE TWO

Variability of Demand For Electricity

Year	Farming Sector (millions of kWh)	PerCent Change	All Other Sectors (millions of kWh	PerCent Change	Avg Annual Demand per farm
1975	251,903	--	3,691,280	--	45,000
1976	297,174	18	4,025,403	9	51,000
1977	328,690	11	3,937,466	-2	54,000
1978	326,848	-1	3,801,369	-3	53,000
1979	396,512	21	3,710,454	-2	64,000
1980	384,801	-3	4,331,844	17	62,000
1981	350,593	-9	4,545,711	5	54,000
1982	478,482	37	4,634,851	2	71,000
1983	523,101	9	4,352,076	-6	74,000
1984	425,866	-19	4,358,719	0	60,000
1985	389,705	-8	4,634,397	6	54,000
1986	500,942	28	5,045,667	9	N. A.

Note: per farm quantities in kWh.
Source: ZESA/ESC Annual Report, 1985;
ZESA files, 1986.

As can be seen, the farming sector demand is fairly irregular. A comparison of the variability in farming demand with the "all other sectors" sector can be made by examining the respective coefficients of variation--the standard deviation expressed as a percent of the mean. The farming sector has a coefficient of 21, while the rest of the system demand has a coefficient of 10. This simply measures what is apparent to the eye when looking at the data: Farm demand is twice as variable as the balance of demand in the nation.

Various interviewees commented on the reasons for the fluctuating demand in the farm sector. The major use of electricity is for irrigation and the linkage between irrigation and the erratic demand is as follows: in most of Zimbabwe irrigation water is surface water, either from rivers or impoundments of various sizes. A number are small impoundments which go dry or nearly so during a drought and therefore--inspite of the need--there is no water to pump and hence electricity use decreases.

Obviously a load that varies substantially from year to year can be expensive to serve--whether it is done from a central grid or if one switches such a load to diesel pump sets--since the capital investment must be put in place although it may not be used at planned levels in (as the figures show) four of twelve years. The irregularities in demand have important implications for investment decisions by both agriculturalists and utility planners.

Table Two contains data which describe other aspects of the farming sector demand. Due to the fluctuations in the data, the rate of growth in demand changes considerably depending on the span of time selected. That is, the growth rate in average annual demand (kWh) from 1975 to 1985 is actually only 1.8 percent. If, however, one measures the growth between 1975 and the historical peak recorded in 1983 the rate is 6.4 percent. The number of farms connected to the system actually decreased in 1976 and 1977.

It is important to note that total demand is dominated by eleven industrial customers who use more than half the power consumed in Zimbabwe; the top 20 consume about 60 percent. Small changes in demand by these few customers can change numbers for the whole system. The largest single user is a fertilizer plant, which is taking the lead in fertilizer production within SADCC. Forecasters at ZESA believe that future growth will come primarily from these few large accounts in the near to mid-term.

Expansion planning for the utility system is the subject of an intensive study being conducted by Gilbert/Commonwealth International, Inc. (of Reading, Pennsylvania, USA) which is being funded by the U. S. Trade and Development Program. The emphasis in that work will be on preparing a system development plan through the year 2010. They will do a projection of peak demand and energy and develop an optimum generation and transmission plan off that. The work will be presented to the Government in late May. While cogeneration and small power production is not the main focus of the study, if the work is done properly opportunities should be identified. [Authors note: As of February 1988 the Gilbert/Commonwealth study has not been released as public information.]

Costs of Pumping

It is helpful to examine some calculations which show the financial costs (i. e., as seen by the user). First among these is the electricity rate or tariff under which electricity is sold to commercial farmers at present. The rate structure is characterized by a (relatively) expensive first block of power which is followed by a quite cheap final increment, all of which is increased by two surcharges:

(a) Block a: is 340 kWh + 10 times the kVA rating of your transformer at 8.5 c/kWh;

(b) Block b: is 1.1 c/kWh;

(c) 1st Surcharge: is an incremental 57%;

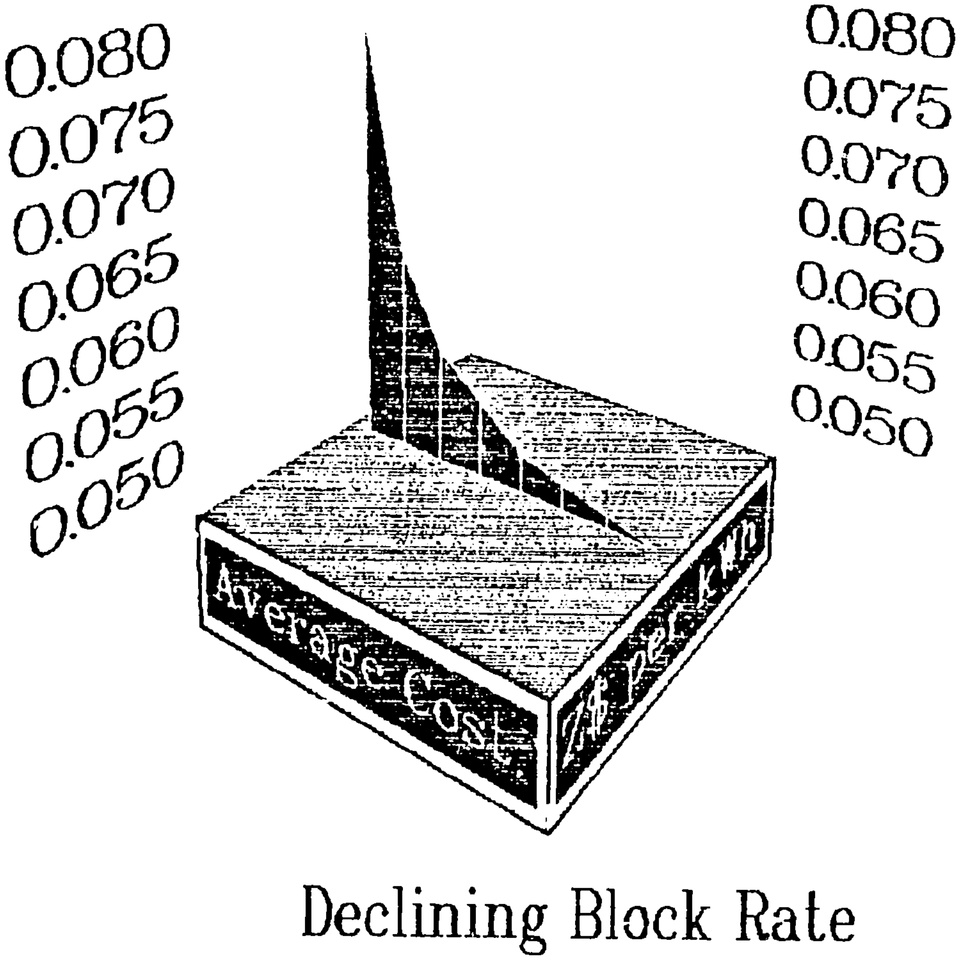
(d) 2nd Surcharge: is a 126% surcharge on the amount thus far calculated.

While this may look fearsome, it is not. It is perhaps awkward to explain, but it is a promotional or declining block rate that is most often used to encourage electricity consumption and may be justified in cases where the long run marginal cost of electricity (at the meter, not the generating plant) is declining. That is, when each new plant brought on or each extension of the line results in lower costs because fixed investment is being spread over more units of output. Figure One on the following page is a graph depicting the declining block rate structure.

ZESA is aware of the problems that this rate structure has caused and is proposing to remedy them. In fact, there is a great amount of activity on the various aspects of the rate question. First, the amalgamation of the several utilities which used to exist means that the tariffs must be combined, too. At present there are nearly forty separate utility tariffs. After July 1, there will be five--if current plans hold. Persons interviewed were willing to discuss the proposed *structure* of the rates, but were not willing to mention any numbers--nor would it have been appropriate of them to do so.

In this paper, the existing rate is criticized quite heavily. It must be said that appropriate officials at ZESA understand these problems and, indeed, they are proposing reasonable remedies. Given the purposes of this paper, it is appropriate to examine the situation as it is and to explain the effects that the existing tariff structure has had on agricultural

Figure One



Declining Block Rate

energy use. As the new structure is implemented, it would be instructive to follow the reactions of the agricultural sector to the changes in price and the structure of electricity prices.

Before moving to an analysis of electric-powered irrigation, it must be said that one piece of research examined contains a reference to a 1983 UNDP/World Bank study which estimated the long run marginal cost of electricity in Zimbabwe at a little more than one cent per kWh. This of course is not likely to be the case. The sparse settlement of the country and the resulting lengthy transmission lines required for new service in rural areas are clear evidence to the contrary. Unfortunately the actual report cited was unavailable for examination and, therefore, at this time it cannot be determined if the original work is wrong or is being misinterpreted. This is quite important since the figure bears a striking resemblence to the per kWh price of the final block of power--prior to the surcharges.

The following example is a hypothetical case which was selected for examination for a number of reasons. First, the Commercial Farmers Union (CFU) has been keeping careful track of input costs for a number of years. Second, this is the most energy intensive part of agriculture and, finally, it concerns wheat which is a crop the government has a specific policy to promote--of this, more later.

The CFU data pertain to an 80 HA wheat field, which is irrigated by an electric-powered pump. Using an amount of water which varies month-by-month in response to the season, they calculate an annual cost for electricity. In addition, they provide capital costs which cover the pumps, motors, pipes, sprinklers, etc. and have estimated repairs and maintenance costs as well. Using these data, an assumed ten percent discount rate, a twenty year equipment life, and a five percent real escalation rate for electricity a standard net present value analysis was run. The resulting sum was divided by the quantity of water pumped during the fifteen years to yield a unit cost present value of Z$0.26 per cubic meter. Running this same analysis for a diesel pumpset yields a per cubic meter cost Z$0.61 per cubic meter. (Appendix One contains the details of these calculations.)

Data provided by CFU also clarifies another question of interest. In this most energy intensive sector, irrigation is about 18 percent of variable costs and the figure has been quite close to that amount each year since 1980.

The Cost of Over-Sized Equipment

Commercial farmers use, on the average, about 60,000 kWh per year. This figure was used to calculate three "typical" electric bills, as follows: A set of twelve monthly charges for the initial block were calculated as were the "demand" charges in the tariff (that which is based on transformer size). These quantities (kWh) were subtracted from the 60,000 and the balance was costed at $0.011 and then surcharges were added. The results are shown below:

Transformer size	Annual Billing	Avg.$/kWh
10 KVA	$3366.25	$0.561
25 KVA	$4200.78	$0.700
50 KVA	$4988.49	$0.831

These transformer sizes were selected because they represent the three most popular levels of service that ZESA provides. Some 65 percent of the farmers are in one of these three groups. By holding the quantity constant, and at a realistic value, one can see the annual cost penalty that arises from over-sizing the level of service. (Recall that the charges are based on transformer size.) Looked at more positively, these are the benefits that a farmer can obtain from managing his own load, installing a smaller transformer, and keeping the peak demand low--even though the quantity of energy remains the same.

ZESA has data showing that there is a large opportunity for resizing (downsizing) on levels of service. A random survey of ten percent of their customers shows that the load factor for the farming sector ranges from 4 percent to 30 percent. That is, on a monthly basis users are taking only 4 percent to 30 percent of the level of service that they are paying for, i. e., of installed transformer capacity. This adds weight to the earlier conclusion regarding the expense of serving these customers.

The net result of the existing rate structure, as calculted by ZESA, is that in 1984 an in-kind subsidy of some $8 million was given to the 7,000 customers who comprise the commercial farming sector. That is, the farming sector cost the utility $8 million more to serve than was collected in revenues from the sector. The new rate which is being considered would move toward cost-based rates and reduce this subsidy.

The rate structure described above plays a central role in understanding the current pattern of irrigation and other energy use in agriculture. Particular effects of the rate will be dealt with in other sections of the paper.

Constraints and Incentives for Irrigation

The major constraint on the development of irrigation at present is simply the limited availability of foreign exchange with which to purchase materials not made in Zimbabwe which are needed for the projects. This conclusion holds true for both public projects and the private sector as well. Irrigation equipment vendors report being able to sell all the diesel engines that they can get. One vendor expected to be allowed to import only about forty units during the next year. Foreign exchange, which is required for many items necessary to install an irrigation system, is quite scarce and is allocated by the government.

RURAL ELECTRIFICATION AND DEVELOPMENT

Twenty four centers around the country have been identified as growth centers which will have power made available to them or have their level of service upgraded. These schemes are subsidized to the extent that the customers must pay not only an agreed upon rate but a connection fee as well while the cost of the transmission line is absorbed by ZESA.

Work on nineteen of these centers has been completed and new demand is appearing at the sites. In some cases additional staff has been transferred from one district to another to assist in secondary development. In the case of two centers (Murewa and Mutoko) the demand for power reached the level where the original plans to run a 33,000 volt line were scrapped and work was begun on a 132,000 volt line. These are clear exceptions to the rule. Most growth centers have a 10 KVA level of service and, while the provision of electric power may be important to local development, the growth in the centers is not going to have a noticeable effect on the level of demand for the farming sector or on the statistics for the system as a whole for some time.

Future plans call for expansion to another 48 centers which have been selected by Provincial governors; ZESA staff has also worked with Provincial Planning teams to anticipate future developments.

There has been no direct and specific effort to create local industry or to run lines to sites of water pumping projects as part of the Rural Electrification program. Moreover, it is a bit soon to begin an evaluation of the program. At some future time, such an effort might well prove instructive.

The Beijer report, cited earlier, enumerates the following small-scale rural industries: beer-makers, builders, tin-smiths, brick-makers, and other skilled artisans. The report deals with these in terms of the use of wood either for structural purposes or as a source of energy. Due to their extremely decentralized nature, they were not surveyed and included in energy estimates contained in the report.

The Beijer report included the running of two scenarios one being "rural" oriented and the other "industry" oriented. While the results were very nearly the same, due to foreign exchange constraints in the model, the rural emphasis scenario estimated that agricultural energy use would actually decline. The explanation being that the scenario included resettlement at the expense of commercial agriculture. Since commercial agriculture is more energy intensive than other sorts, energy use would decline. In the industry oriented case, agricultural energy declined as well. The small decline arises simply because industry is being emphasized in the development plan in the model.

One of the more germane issues raised by the investigators in the Beijer report is the failure to use wood wastes. While this would appear to be an area in which self-generation or small power production could be encouraged, it is not mentioned in the report. When this point was made to several interviewees, they could add nothing from experience nor could they provide any references to work on the topic or "resident" experts. This topic calls for further investigation.

The Need for Capital Saving Investments

In a foreign exchange constrained environment, it is imperative that efforts of two sorts be pursued. First, investments must be capital-saving. It may not be enough that, taken alone, a particular investment show a sufficient rate of return. Second, efforts must be made to allocate capital to reducing current account outflows, i. e., investments which permit domestic production of goods which could just as well be made in-country rather than imported.

These investment strategies have direct implications for energy and, especially, agricultural energy use. First, investments in cogeneration equipment which can use agricultural wastes (among others) as a feedstock can often simultaneously produce electricity at a price below that of grid power and supply process heat or steam for industrial or agricultural processing operations. Zimbabwe has a stunning example of how this can be accomplished.

The Triangle Estates sugarcane mill generates its own power for running the entire estate, including irrigation. Triangle does provide power to some neighbors; they are, however, billed by ZESA. It generates power for nine months of the year using bagasse and with coal for the 3 months in which there is no cane being crushed. In addition, Triangle is the source of the ethanol which is used to extend the imported gasoline supply by about 14 percent. Moreover, carbon dioxide is taken off the fermentation process and is a profitable by-product. Clearer examples of capital saving energy investments do not exist. The scale of the operation, is however, simply immense: 83,000 hectares with an equal amount available for further industrial and agricultural development.

The Economic Environment for Private Sector Power

At present there do not appear to be any special incentive programs which would encourage or promote private power development. The Triangle Estates project, mentioned earlier, began in 1927 and developed self-sufficiency largely out of necessity. Even though capital is scarce, there is no widespread experience with cogeneration--though there is some autogeneration experience--and the rate structure indicates (quite wrongly) that there is an apparent abundance of cheap electric power. It is no wonder that cogeneration schemes have not been developed.

The declining block rate, previously described, would seem to be a major impediment to competing in the "electricity marketplace." The average price of power declines quite quickly. Table Three shows the results of calculating various quantities of energy supplied during a single month through a 150 KV system.

TABLE THREE

Declining Average Costs of Electricity

Quantity (kWh)	Average Cost per kWh
11,840	$0.080
21,840	.061
31,840	.054
41,840	.051
51,840	.048
61,840	.047
71,840	.046
81,840	.045

Source: Calculated based on existing ZESA Tariff #5.

It should be noted that the marginal cost goes to $0.039 after block one and remains at that level, while average costs continue to decline over the range examined.

The question of whether or not rural residents (either large scale commercial farmers or residents of growth centers) should be served at subsidized rates is separate from the question of how to provide that power. It is likely that a strategy of using small power producers and/or cogenerators to carry out a rural electrification/economic and social development program could be accomplished more quickly and at a lower cost than it could be with grid power.

Discussions with ZESA personnel indicated no hesitancy on their part to purchase power or bill users (as with Triangle) but had never been confronted with the idea of actually promoting such activity. On the other hand, at the time they run their lines into an area, they have taken over and replaced some small (very small) "private utilities" such as a welding shop which supplied power to neighbors.

PURSUIT OF THE LEAST COST OPTION

The pursuit of energy services at the least cost is simple in concept, but becomes much more complex in practice. The principle behind the concept is this: there is no demand for energy *per se*. The demand for energy is a derived demand, i. e., derived from the demand for goods and services which are offered in the economy. In short, one wants hot water, a warm room, or water lifted; consumers do not want gasoline, electricity, or a windmill. If you want water lifted and there are several ways of doing it, "least cost thinking" says that you should do it the cheapest way.

While this sounds simple, it becomes difficult in practice and there are three main reasons that it does. First, the information about the costs and efficiency of an option might not be readily available to the person making the purchase decision. Second, there may exist distortions or dislocations in the economy which effectively preclude the purchase of the most efficient technology. Third, the more efficient alternative may require a large, up-front capital investment which is beyond the reach of the would-be purchaser.

For example, a least-cost solution to a particular water pumping problem might be a pump set sized so as to run virtually continuously pumping water into a storage facility during the night and running directly into the field during the day. A smaller pump would use less energy (electric, diesel, or other) and, even with the added cost of storage, might provide a given level of irrigation more cheaply. Problems arise, for example, when the smaller pump is not available either because it is not in the manufacturer's catalog or when the purchaser is not aware of the lower-cost technology.

To make sure that consumers are aware of alternatives, ZESA has an information service which commercial farmers can use to size equipment and to determine the level of electrical power needed for a given menu of equipment. This service is little used, however. In addition, AGRITEX publishes a nation-wide listing of companies which provide irrigation products and services: "Zimbabwe Irrigation Products and Services Directory." Perhaps the coming of a new rate and the loss of the subsidy will create a new interest in understanding more about the efficiency of energy consumption.

The previously mentioned shortage of foreign exchange creates a major distortion on the supply side since it limits the importation of both new equipment and the materials needed for their manufacture. Prices are controlled to prevent (minimize) gouging, but equipment is simply not available. Moreover, reconditioned used equipment has become quite expensive. The newspaper contains advertisements by people wanting pump sets, not people trying to sell them.

The availability of credit is being addressed by the Government of Zimbabwe which has established an irrigation loan program through an Agricultural Finance Commission. Conceptually this is a correct response to the problem, though actually establishing a credit facility and making it work is a very difficult and time-consuming task. There are indications that the implementation of this program is going more slowly than had been anticipated. It is very likely that a loan program can work, if due consideration is given to the difficult legal and institutional arrangements can be accounted for in the program structure. Where land tenure issues arise and cash-flows do not come directly to individuals but to associations instead, some trial and error in implementation is to be expected.

CONCLUSION: PROSPECTIVE PROJECTS

1. Irrigation strategy for Zimbabwe. The nation's food production goals are ambitious but can likely be achieved, even with the tightness in foreign exchange. There is a recognition of a need for a clearly stated "strategy" to guide irrigation investments, which are now being done with only rough knowledge of the delivered cost of water. A small analytic team could assist in the development of an analytic procedure for ranking investments according to agreed upon criteria. While energy is only one of the factors affecting costs of water, it can be significant at the project level. A effort to support the Ministry of Lands, Agriculture, and Rural Resettlement could be quite helpful.

2. Animal and Human-powered pumps. There is a significant need to know more about the operation of human and animal-powered pumps and to improve these designs. The need is primarily for the small commercial and, expecially, for the farmers who work the communal lands--where one-half the nation's cotton crop was produced last year. Improving the situation for these farmers is a major goal of the nation and an effort to support improved pumping would pay dividends.

3. Electric Supply Options. At present the Trade and Development Program is supporting a study of supply options for the Zimbabwe Electric Supply Authority. This study will come at a time when they have just changed (raised) all their utility rates and when the shortage of foreign exchange is becoming more and more acute. It is likely that the World Bank financing of additions to the power supply will be predicated on the implementation of the planned rate increases. There are many good reasons to be wary of large scale additions to the generation facilities--but the options they are likely to be presented with are apt to be only (a) rebuild hydro and (b) add coal-fired units at existing site.

Given the situation, there should be receptivity to studies which would lead to the development of projects which save capital and generate power to support rural development. Until the shape of the Gilbert-Commonwealth proposed options are known, it is premature to propose a study of this nature.

4. Import Substitution in electric expansion plans. A useful small project could be undertaken to assist ZESA in identification of US firms who have technology that could be licensed for production in Zimbabwe. Example: electric insulators for power lines. This specific example was cited by Mike Netscher (ZESA) as an initiative that is small but useful.

5. Liquid Fuels. Every country in southern Africa has a liquid fuels problem of greater or lesser proportions and Zimbabwe is no exception. Current gasoline supplies are extended with about 13% ethanol, from sugar cane. Plans exist to roughly double the supply of ethanol, which might be exported to other southern Africa countries.

The US DOE is beginning serious policy work on methanol (from coal, natural gas, biomass) and are trying to better understand the world-wide energy and environmental implications of moving to methanol as a gasoline substitute and/or replacement in the longer run. While DOE is going to focus its attention on Asia, the problem is likely to be more acute in the SADCC countries.

6. Wood Wastes. In spite of the fact that the Beijer report called attention to the opportunity, no projects have been undertaken to make use of the wood wastes in the forest products industry. Based on the situation elsewhere, there appears to be an opportunity for the industry to become energy self-sufficient and it should be examined very carefully.

Appendix I

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Appendix II

Comparative Costs of Diesel and Electric Powered Pumpsets

As noted in the text, this example was chosen because the Commercial Farmers Union had, for a number of years, kept input cost data as well as gross and net selling prices on a hypothetical 80 ha wheat plot which was irrigated with an electric-powered pumpset. In order to gain a sense of the difference in energy costs, a diesel-powered pumpset of comparable performance (equal water output) was designed and costed-out with the considerable assistance of Mr. P. C. DeVillez of Stewarts + Lloyds in Harare.

These data were analyzed using standard discounted cash flow techniques; the estimated comparative costs are shown in the spreadsheet which follows.

COMPARATIVE COSTS: DIESEL AND ELECTRIC

	DIESEL PUMPSET					**	ELECTRIC PUMPSET				
Year	Capital	Diesel	O&M	Total Recurrent	Total Cost	**	Capital	Electric	O&M	Total Recurrent	Total Cost
1	201274	76008	8070	84078	285352	**	195082	22500	6500	29000	224082
2		79808	8070	87878	87878	**		23625	6500	30125	30125
3		83799	8070	91869	91869	**		24806	6500	31306	31306
4		87989	8070	96059	96059	**		26047	6500	32547	32547
5		92388	8070	100458	100458	**		27349	6500	33849	33849
6		97008	8070	105078	105078	**		28716	6500	35216	35216
7		101858	8070	109928	109928	**		30152	6500	36652	36652
8		106951	8070	115021	115021	**		31660	6500	38160	38160
9		112298	8070	120368	120368	**		33243	6500	39743	39743
10		117913	8070	125983	125983	**		34905	6500	41405	41405
11		123809	8070	131879	131879	**		36650	6500	43150	43150
12		129999	8070	138069	138069	**		38483	6500	44983	44983
13		136499	8070	144569	144569	**		40407	6500	46907	46907
14		143324	8070	151394	151394	**		42427	6500	48927	48927
15		150491	8070	158561	158561	**		44548	6500	51048	51048
16		158015	8070	166085	166085	**		46776	6500	53276	53276
17		165916	8070	173986	173986	**		49115	6500	55615	55615
18		174212	8070	182282	182282	**		51570	6500	58070	58070
19		182922	8070	190992	190992	**		54149	6500	60649	60649
20		192068	8070	200138	200138	**		56856	6500	63356	63356

NPV per M3 .61 NPV per M3 .26

NOTE: SEE ASSOCIATED TEXT FOR EXPLANATIONS AND ASSUMPTIONS.
ALL VALUES IN ZIMBABWE DOLLARS

Appendix III

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APPENDIX D

LIST OF WATER MANAGEMENT SYNTHESIS II PROJECT REPORTS

WMS 1 Irrigation Projects Document Review

Executive Summary
Appendix A: The Indian Subcontinent
Appendix B: East Asia
Appendix C: Near East and Africa
Appendix D: Central and South America

WMS 2 Nepal/USAID: Irrigation Development Options and Investment Strategies for the 1980s

WMS 3 Bangladesh/USAID: Irrigation Development Options and Investment Strategies for the 1980s

WMS 4 Pakistan/USAID: Irrigation Development Options and Investment Strategies for the 1980s

WMS 5 Thailand/USAID: Irrigation Development Options and Investment Strategies for the 1980s

WMS 6 India/USAID: Irrigation Development Options and Investment Strategies for the 1980s

WMS 7 General Asian Overview

WMS 8 Command Area Development Authorities for Improved Water Management

WMS 9 Senegal/USAID: Project Review for Bakel Small Irrigated Perimeters Project No. 685-0208.

WMS 10 Sri Lanka/USAID: Evaluation Review of the Water Management Project No. 383-0057.

WMS 11 Sri Lanka/USAID: Irrigation Development Options and Investment Strategies for the 1980s

WMS 12 Ecuador/USAID: Irrigation Sector Review

WMS 13 Maintenance Plan for the Lam Nam Oon Irrigation System in Northeast Thailand

WMS 14 Peru/USAID: Irrigation Development Options and Investment Strategies for the 1980s

WMS 15 Diagnostic Analysis of Five Deep Tubewell Irrigation Systems in Joydebpur, Bangladesh

WMS 16 System H of the Mahaweli Development Project, Sri Lanka: 1982 Diagnostic Analysis

WMS 17 Diagnostic Analysis of Farm Irrigation Systems on the Gambhiri Irrigation Project, Rajasthan, India: Volumes I-V

WMS 18 Diagnostic Analysis of Farm Irrigation in the Mahi-Kadana Irrigation Project, Gujarat, India

WMS 19 The Rajangana Irrigation Scheme, Sri Lanka: 1982 Diagnostic Analysis

WMS 20 System H of the Mahaweli Development Project, Sri Lanka: 1983 Diagnostic Analysis

WMS 21 Haiti/USAID: Evaluation of the Irrigation Component of the Integrated Agricultural Development Project No. 521-0078.

WMS 22 Synthesis of Lessons Learned for Rapid Appraisal of Irrigation Strategies

WMS 23 Tanzania/USAID: Rapid Mini Appraisal of Irrigation Development Options and Investment Strategies

WMS 24 Tanzania/USAID: Assessment of Rift Valley Pilot Rice Project and Recommendations for Follow-On Activities

WMS 25 Interdisciplinary Diagnostic Analysis of and Workplan for the Dahod Tank Irrigation Project, Madhya Pradesh, India

WMS 26 Prospects for Small-Scale Irrigation Development in the Sahel

WMS 27 Improving Policies and Programs for the Development of Small-Scale Irrigation Systems

WMS 28 Selected Alternatives for Irrigated Agricultural Development in Azua Valley, Dominican Republic

WMS 29 Evaluation of Project No. 519-0184, USAID/El Salvador, Office of Small-Scale Irrigation -- Small Farm Irrigation Systems Project

WMS 30 Review of Irrigation Facilities, Operation and Maintenance for Jordan Valley Authority

WMS 31 Training Consultancy Report: Irrigation Management and Training Program

WMS 32 Small-Scale Development: Indonesia/USAID

WMS 33 Irrigation Systems Management Project Design Report: Sri Lanka

WMS 34 Community Participation and Local Organization for Small-Scale Irrigation

WMS 35 Irrigation Sector Strategy Review: USAID/India; with Appendices, Volumes I and II (3 volumes)

WMS 36 Irrigation Sector Assessment: USAID/Haiti

WMS 37 African Irrigation Overview: Summary; Main Report; An Annotated Bibliography (3 volumes)

WMS 38 Diagnostic Analysis of Sirsia Irrigation System, Nepal

WMS 39 Small-Scale Irrigation: Design Issues and Government-Assisted Systems

WMS 40 Watering the Shamba: Current Public and Private Sector Activities for Small-Scale Irrigation Development

WMS 41 Strategies for Irrigation Development: Chad/USAID

WMS 42 Strategies for Irrigation Development: Egypt/USAID

WMS 43 Rapid Appraisal of Nepal Irrigation Systems

WMS 44 Direction, Inducement, and Schemes: Investment Strategies for Small-Scale Irrigation Systems

WMS 45 Post 1987 Strategy for Irrigation: Pakistan/USAID

WMS 46 Irrigation Rehab: User's Manual

WMS 47 Relay Adapter Card: User's Manual

WMS 48 Small-Scale and Smallholder Irrigation in Zimbabwe: Analysis of Opportunities for Improvement

WMS 49 Design Guidance for Shebelli Water Management Project (USAID Project No. 649-0129) Somalia/USAID

WMS 50 Farmer Irrigation Participation Project in Lam Chamuak, Thailand: Initiation Report

WMS 51 Pre-Feasibility Study of Irrigation Development in Mauritania: Mauritania/USAID

WMS 52 Command Water Management -- Punjab Pre-Rehabilitation Diagnostic Analysis of the Niazbeg Subproject

WMS 53 Pre-Rehabilitation Diagnostic Study of Sehra Irrigation System, Sind, Pakistan

WMS 54 Framework for the Management Plan: Niazbeg Subproject Area

WMS 55 Framework for the Management Plan: Sehra Subproject Area

WMS 56 Review of Jordan Valley Authority Irrigation Facilities

WMS 57 Diagnostic Analysis of Parakrama Samudra Scheme, Sri Lanka: 1985 Yala Discipline Report

WMS 58 Diagnostic Analysis of Giritale Scheme, Sri Lanka: 1985 Yala Discipline Report

WMS 59 Diagnostic Analysis of Minneriya Scheme, Sri Lanka: 1986 Yala Discipline Report

WMS 60 Diagnostic Analysis of Kaudulla Scheme, Sri Lanka: 1986 Yala Discipline Report

WMS 61 Diagnostic Analysis of Four Irrigation Schemes in Polonnaruwa District, Sri Lanka: Interdisciplinary Analysis

WMS 62 Workshops for Developing Policy and Strategy for Nationwide Irrigation and Management Training. USAID/India

WMS 63 Research on Irrigation in Africa

WMS 64 Irrigation Rehab: Africa Version

WMS 65 Revised Management Plan for the Warsak Lift Canal, Command Water Management Project, Northwest Frontier Province, Pakistan

WMS 66 Small-Scale Irrigation -- A Foundation for Rural Growth in Zimbabwe

WMS 67 Variations in Irrigation Management Intensity: Farmer-Managed Hill Irrigation Systems in Nepal

WMS 68 Experience with Small-Scale Sprinkler System Development in Guatemala: An Evaluation of Program Benefits

WMS 69 Linking Main and Farm Irrigation Systems in Order to Control Water

- Volume 1: Designing Local Organizations for Reconciling Supply and Demand
- Volume 2: A Case Study of the Niazbeg Distributary in Punjab, Pakistan
- Volume 3: A Tank System in Madhya Pradesh, India
- Volume 4: The Case of Lam Chamuak, Thailand
- Volume 5: Two Tank Systems in Polonnaruwa District, Sri Lanka