Hydraulics Research
Wallingford

Schistosomiasis Control at Mushandike Irrigation Scheme:

Proceedings of Seminar for Collaborating Organisations, October 1986

In collaboration with:
Department of Agricultural Technical and Extension Services and
Blair Research Laboratory, Zimbabwe

Report OD 88
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ABSTRACT

In many tropical regions the link has been established between an increase in the area of land under irrigation and an increase in prevalence of the debilitating, and sometimes fatal, parasitic disease schistosomiasis. In a research project based on the Mushandike Irrigation Scheme in Zimbabwe, an assessment is being made of the extent to which engineers and planners can help to control the transmission of this disease through careful design and operation of the irrigation works and domestic facilities.

The success of the research depends on close collaboration not only involving the three principal organisations but also involving other agencies responsible for planning and financing, for irrigation design, construction and management, for operating the dam and canal system and for health and education provision for the Mushandike Irrigation Scheme. For this reason it was agreed that a short seminar should be held in Masvingo on 22 and 23 October 1986 to bring together a representative group of senior officials from the interested agencies to review the progress of the research and to assess what further measures are required to ensure its success.

This report contains the papers presented at the seminar and a summary of the discussions. Together the papers provide a comprehensive introduction to the research project covering the background to the study, a description of the factors affecting schistosomiasis transmission in Zimbabwe, a history of the irrigation scheme, an account of the engineering measures being introduced in its design and construction, a study of water supply and sanitation technologies and an account of the programme for monitoring schistosomiasis transmission at Mushandike.

The 600ha Mushandike Irrigation Scheme is being implemented over a two year period. At the time of the seminar the first 35ha were under irrigation.

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The research project

In early 1985 an agreement was reached between the then Department of Rural Development, the Blair Research Laboratory, Ministry of Health and the Overseas Development Unit, Hydaulics Research, Wallingford, UK to undertake a collaborative research project into the effectiveness of engineering measures for the control of schistosomiasis on small holder irrigation schemes in Zimbabwe. The 600ha irrigated resettlement scheme at Mushandike was selected as a pilot project. Using funds from the UK Overseas Development Administration, Hydraulics Research seconded an engineer for a period of approximately 12 months to work with local Zimbabwean staff on the designs for the first phase of the irrigation scheme. The schistosomiasis control measures introduced were in accordance with criteria which were drawn up in advance through consultation between the collaborating organisations. These measures seek control by:

1. eliminating the habitats of the aquatic snails which are vectors of the disease (through canal lining, design of structures, operation to maximise drying-out of canals and water level fluctuations in reservoirs);

2. minimising human contamination of water (through provision of pit latrines);

3. minimising human contact with water (through careful village location and provision of safe water and washing facilities nearby).

Using its in-house development teams the Department of Rural Development had completed contruction of 50ha by June 1986 and had a further 50ha virtually completed by the time of the seminar. Irrigation began on 35ha with a winter wheat crop which was being harvested at the time of the seminar.

The purpose of the seminar

The success of the research depends on close collaboration not only involving the three principal organisations but also involving other agencies responsible for planning and financing, for irrigation design, construction and management, for operating the dam and canal system and for health and education provision for the Mushandike Irrigation Scheme. For this reason it was agreed that a short seminar should be held in Masvingo on 22 and 23 October 1986 to bring together a representative group of senior officials from the interested agencies to review the progress of the research and to assess what further measures are required to ensure its success. Representatives of the following organisations attended (a total of 26 people):

- Department of Agricultural Technical and Extension Services (AGRITEX), Ministry of Lands, Agriculture and Rural Resettlement;
- Blair Research Laboratory, Ministry of Health;
- Department of Rural Development, Ministry of Local Government;
- Ministry of Health;
- Ministry of Energy and Water Resources and Development;
- Agricultural and Rural Development Authority (ARDA);
- University of Zimbabwe;
- Liverpool School of Tropical Medicine;
- Hydraulics Research, Wallingford.

The seminar comprised the six keynote papers contained in this report. These cover all aspects of the project. A seventh paper which is included here as an appendix was not presented at the Seminar but was circulated to delegates as a background paper. A considerable amount of time was allowed for discussion. In addition, one whole morning was spent at the irrigation scheme.

Summary of discussions on the keynote papers

In his introductory remarks Dr Jewsbury, of the Liverpool School of Tropical Medicine, gave a brief outline of the life cycle of the schistosome parasite. He drew particular attention to the point in the life cycle at which human infection occurs through people entering infected water and their skin being penetrated by the minute larval stage of the parasite, cercaria. He distinguished three categories of human activity which account for most instances of water contact leading to new infection: occupational, domestic and recreational. In irrigation schemes, occupational contact occurs during the operation and maintenance of canals and water control structures, during the application of water to crops and during other cultivation activies. Domestic contacts arise from the collection of drinking water, personal hygiene and the washing of clothes. Recreational activities include swimming and play (mainly by children) and, although not purely recreational, fishing. Dr Jewsbury warned that although the focus of the research and seminar, being an irrigation scheme, might suggest that occupational contact is the major concern, domestic and recreational activities are likely to be equally important in the transmission of the disease. It is for this reason that an attempt has been made to keep the research as broad as possible involving organisations which are responsible for rural health and the planning of villages along with those responsible for irrigation activities.

The seminar was of greatest benefit where discussion focussed on topics which provided an opportunity for memebers of one department or profession to gain an understanding of the factors which govern the decisions of those in other departments or professions.

Engineers where appreciative of the biological information presented on the life-cycle of the schistosome parasite and how it might be used in designing control measures. There was general agreement that public understanding of the causes and importance of the disease was poor not least amongst the rural population in Zimbabwe where traditional beliefs about its transmission (many unrelated to the true causes) have been widespread even until recent times. For this reason the educational programme accompanying the research project was seen to be of considerable value. The importance of schistosomiasis in the eyes of public health officials in Zimbabwe is indicated by the fact that, in terms of the number of notified cases, schistosomiasis is second only to diarrhoea in its occurrence. Perhaps the most important characteristic of schistosomiasis to emerge in the presentations concerning its epidemiology is the extremely focal nature of the disease. In planning control measures both for a specific scheme and for a region or country it is therefore dangerous to attempt generalisations: high rates of transmission may occur in an isolated locality within an area with generally low transmission rates.

Participants with a medical or biological training showed interest in the factors which cause engineers to select a particular design when they are planning and building irrigation schemes. The feasibility of modifying standard design practice to achieve control of disease transmission was discussed. A notable example was in the design and operation of night storage reservoirs. Details of night storage reservoirs on ARDA schemes in the Sabi Valley were presented which show that the control of snails by draining and drying reservoirs can only be considered where suitable soils are present in the floor and bunds of the reservoir. For example, at Chisumbanje the local clay forming the bed is only 20-30cm thick and would crack in a matter of several days. Similarly the imported clay blanket at Sanyati is vulnerable by cracking. By contrast the reservoir at

Middle Sabi could be dried out for as long as one wished without risk of damaging it. On the question of canal linings, the possibility of using alternative materials or methods was raised in order to avoid the cost of concrete construction. Investigations have been made in Zimbabwe into the use of sand cement, for example, but although this is cheaper initially it is far less durable than cement. Finally the issue of what provision should be made for surface drainage was discussed. At present earth ditches are provided at the sides of access roads to collect runoff from the fields and discharge it in areas of uncleared land or natural water courses nearby. Some delegates felt that these methods of disposal may not be adequate under heavy rainfall and that cultivation might gradually encroach on the drain lines reducing their capacity. However, the AGRITEX personnel are aware of the dangers and would prefer to wait until they have studied the operation of the present system before introducing further drainage works.

The question of how to design suitable village areas for the farmers touched the interests and responsibilities of a large number of the delegates. There was extensive discussion not only following the presentation of the papers but also during the field visit and concluding discussion on village location and on the provision of water and sanitation. The village on the Misty Vale block was considered to be well located within easy access of the fields but away from the irrigation canals and reservoirs. By contrast the one on Invicta block was identified as having a hazardous location close to night storage reservoirs and with a secondary canal running through the middle. A further village proposed for the head of Ashcroft was considered to have a poor location since it was close to the main canal. In each case the adequacy of the water supply will influence the extent to which disease transmission occurs close to these villages.

Field visit

On the morning of 23 October the participants visited Mushandike Irrigation Scheme, see Plates 1-4. Time was spent studying the feeder canals, storage reservoirs and infield works of the Misty Vale block and the harvesting of the winter wheat crop of 35ha (being undertaken without mechanisation). The appearance that a healthy crop had been produced was confirmed by farmers who claimed yields of 6½-7t/ha. The night storage reservoirs caused great concern because of their shallow depth, the large quantities of aquatic weed growing and the large numbers of aquatic snails observed (although not the host species of schistosomiasis). AGRITEX officials explained that draining and cleaning of the reservoirs had been delayed until after the seminar.

The village at Misty Vale had many wattle and daub houses with thatched roofs constructed to a high standard. No household pit latrines had been completed although some of the pits had been dug. There are two boreholes close to the village but the near one has fallen into disuse due to its poor yield. The remaining borehole appears to be used extensively and to have a sufficient yield but no apron had been constructed and an unhealthy swamp area had developed downstream. Ministry of Health officials informed participants that a village health assistant had now been appointed who would organise the villagers in the construction of an apron and drain.

At Ashcroft, delegates observed the irrigation works being completed on Ashcroft ready for a summer crop. The Department of Rural Development teams were seen constructing field canals and secondary canal structures during the visit. The proposed locations of two villages were also visited in order to observe the potential health problems which had been raised during the previous day's discussion.

Concluding discussion

There was general agreement that the standard of construction of the Mushandike Irrigation Scheme and yields obtained from the first area to enter production were highly commendable. Delegates also acknowledged the difficulty of achieving schistosomiasis control on such a scheme within the budget constraints which apply. Nevertheless, through increased understanding and interdepartmental co-operation which the seminar had sought to achieve the best use could be made of the resources available.

Dr Jewsbury, in his summary of the proceedings, highlighted six questions which should be addressed if the objectives of the research project are to be achieved. The first three were of immediate importance:

(i) What should be done concerning the Misty Vale night storage reservoirs? This particular case is expected to be exceptional because of the shallowness of the dam which renders a policy of water-level fluctuation ineffective since the snails can survive on the bed of the reservoir even when the water level is at its maximum. The draining and weed clearing to be undertaken by AGRITEX immediately after the seminar would have some effect. For the future it was proposed that a brief document giving more detailed guidance on the design and operation of night storage reservoirs should be produced.

(ii) Can the borehole water supplies to the villages be supplemented should they be found to be inadequate? Provincial Health Officials welcomed the idea of an improved water supply especially one which could in due course be extended to provide individual household connections. From the Ministry of Local Government, however, it was noted that financial allocations for water supply had now been spent on the boreholes which had been chosen as the most appropriate option at the start of the project. Nevertheless, it was agreed that a review of other alternatives would be made for future reference including the preparation of estimated costs for a piped supply from the Mushandike Dam.

(iii) Is the sanitation provision in the villages adequate in view of the fact that no household pit latrines have been completed? Provisional Health Officials were in no doubt that the latrines would be built and, judging by the construction of the houses, to a high standard. The reason for the failure to complete any latrines to date was the pressure of work on the farmers since their arrival on the scheme in tending their crops and building their homes.

The second three questions raised by Dr Jewsbury were of a more long-term nature.

(i) How can we ensure that in future the location of villages is optimised? Despite its great importance delegates were not in favour of any formal interdepartmental mechanism to oversee village location. The officials from the Department of Rural Development who are responsible for this aspect of planning are now fully aware of the requirements to achieve disease control.

(ii) Are we able to evaluate the cost of the control measures introduced? Figures are not yet available but this aspect is to be pursued.

(iii) Do we know exactly what velocity is required in canals to achieve snail control? Dr Jewsbury suggested this as one area of useful future research since the high velocities being achieved at Mushandike could not be achieved on land with shallower gradients.

Acknowledgements

The research project and seminar are the fruit of a collaborative agreement between Hydraulics Research, the Department of Rural Development/AGRITEX and the Blair Research Laboratory. Grateful acknowledgement is made to the Zimbabwean authorities for the inputs of staff time and resources made to the project and seminar through the Zimbabwean parties and to the individuals from these organisations whose enthusiastic support has been invaluable. Funding is being provided by the UK Overseas Development Administration for the participation of Hydraulics Research in the research and for part of the cost of monitoring the irrigation scheme. Particular thanks are expressed to those who contributed papers to this seminar and to all those who, by their participation, contributed to its success.

Plate 1: Harvesting winter wheat on Misty Vale

Plate 2: Delegates inspecting night storage reservoir, Misty Vale

Plate 3: Delegates watching tertiary canal construction, Ashcroft

Plate 4: Free draining drop structure in operation, Ashcroft

SEMINAR PAPERS

1 INTRODUCTION TO THE SCHISTOSOMIASIS CONTROL RESEARCH PROJECT

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1.1 Introduction

The aim of this paper is to explain why Hydraulics Research (HR) became involved in the schistosomiasis control research project. To assist in this explanation a brief background to the company and the Overseas Development Unit (ODU) will be given. The overall objectives of undertaking this research will be shown in the context of the other irrigation and water resources research that the ODU is undertaking.

1.2 Hydraulics Research

Hydraulics Research is an independent, non profit distributing company registered in the UK. It was formed in 1982 to take over and extend the work of the British Government's Hydraulics Research Station, an organisation with 35 years experience of undertaking research and project studies in civil engineering hydraulics and related areas.

The company is organised into four departments:

River engineering
Tidal engineering
Maritime engineering
Irrigation and water resources (ODU)

Work, including basic research and site specific design studies, is commissioned by clients and undertaken in one of these four departments. Studies are usually based around computational models, physical models, field studies and desk studies or any combination of these. Many of the staff in the company are engineers, scientists and mathematicians. Company staff number approximately 250 at present. In addition to the specialised professional staff there are extensive laboratory facilities, well equipped field survey teams and large computers.

Work experience covers the whole range of open surface hydraulics including bridge crossings, flooding problems, dam spillway performance, dredging in estuaries and harbours, coastal protection and offshore engineering. Clients seeking the advice and help of Hydraulics Research are primarily government ministries, national utilities and public authorities, both in Britain and overseas, and civil engineering consultants and contractors.

1.3 Overseas Development Unit

Since its inception in 1951 Hydraulics Research has frequently undertaken specific studies for the British Overseas Development Administration (ODA). These tasks are often funded by the geographical departments of the ODA, (technical co-operation funds), and are directed towards solving specific problems arising out of the ODA's activities.

Since 1973, the ODA has commissioned work of a general nature relevant to developing countries through the creation of the Overseas Development Unit (ODU) at HR. The creation of the Unit complemented the specific studies by providing a consistent and, within limits, predictable flow of funds; thus enabling HR to assign a team of people to the full-time study of water problems that commonly arise in developing countries. The financial and technical framework within which the Unit operates is set at an annual management meeting chaired by the Principal Engineering Adviser of the ODA.

This form of institutional commissioning of research has certain advantages for the funding and managing of research and development activities. Research activities can be planned over several years without the uncertainty of rapid fluctuations in budget amounts. This is particularly important to us as most of the research work in the ODU is based overseas.

The ODU was, therefore, set up at HR to carry out research into the control of water resources and irrigation in developing countries. The work of the ODU is of a general rather than a specific nature. Attempts are made to identify, through visits and discussions in the developing countries, water related problems that have a fairly widespread occurrence. Programmes of research into these problems are then proposed. During this process the ODU is assisted by the professional advisers, primarily the engineering advisers, at the ODA. In selecting projects care is taken to ensure that the results of the study will be of interest to more than one country.

The principal objectives of the Unit can be summarised as follows:

(a) To undertake research into water problems that are peculiar to, or acute in, the developing countries; with particular attention to problems that are common to significant numbers of these countries.

(b) To disseminate and promote the interchange of technical information on the research problems that the ODU addresses.

To pursue this research it is necessary to gain site experience from a wide range of locations. Projects in particular countries are therefore undertaken in collaboration with organisations (usually government ministries like irrigation departments) in developing countries. The smooth running of the research projects depends upon the success of the collaboration that can be achieved.

The following basic themes comprise the research programme of the ODU:

- Irrigation water management
- Reservoir sedimentation
- Erosion control in catchments
- Sediment control in canals
- Drainage and land reclamation
- Minor irrigation design
- Canal seepage
- Health aspects of irrigation

It is this last theme that we will discuss further in this seminar. However, before we discuss the reasons why we are studying health aspects of irrigation it will be useful to explain briefly how projects are set up.

1.4 Setting up a Research Project

The first step in setting up a project is an exploratory visit to a country by a senior member of the ODU or a consultant engaged for that purpose. A problem is identified that lies within the scope of the objectives listed earlier. The willingness of the likely collaborating organisation(s) to engage in a joint study of the problem is ascertained. If agreement is reached in principle then a draft research proposal is prepared for approval by the host country and by the ODA. Projects only proceed when the research proposal has been approved by all parties concerned, this often takes some time particularly if several organisations are involved. The proposal contains a discussion of the problem and a list of tasks that each party will do. We usually require the assignment of technical staff, back-up facilities and local transport from our collaborators. In some cases it is possible to arrange separate sub-contracts to provide for the funding of collaboration inputs if these inputs could not otherwise be found. The ODU for its part provides: technical staff in the UK to analyse results and prepare reports; essential equipment; and relevant training of collaborators. Counterpart staff are able to visit HR at Wallingford in the UK to attend training sessions. These are often of several months duration and are arranged by the British Council. Short-term visits by ODU staff are also made at key stages during the project. These are usually of two to three weeks duration, though, where the specific need arises, ODU staff can spend longer overseas. This was the case in the early stages of the project under discussion; an irrigation engineer was posted to Masvingo for a total of twelve months to provide design assistance for the Mushandike scheme.

The dissemination of research results to those associated with the project and those interested in the subject is most important. Reports are distributed widely, articles are written for technical journals and conferences, symposia and workshops are organised with collaborators to bring together engineers and researchers. This present seminar is, in fact, an example of our dissemination and we hope it will be found to be a useful forum for discussion amongst researchers and practising irrigation engineers and planners.

1.5 Schistosomiasis control research project

This project comes under the terms of the research theme on the health effects of irrigation schemes and was initiated in response to a request from the advisers in ODA.

There is a clear link between the expansion of irrigated land and increased transmission of this parasitic disease in many parts of Africa, Jewsbury (1984). Awareness of the detrimental effects to human health due to the increase in the amount of irrigation has been growing and it was felt that the engineering aspects of schistosomiasis control need more attention. As Mott (1984) points out 'it needs to be recognised at the planning stage that control of disease due to schistosomiasis is feasible'. For our purposes we define engineering aspects as the controls that can be incorporated into the design of an irrigation scheme either related to the physical works or the way water is distributed and scheduled around the scheme.

Other papers in this seminar will deal with the nature of the disease and its occurrence in Zimbabwe and elsewhere. However, just to show the magnitude of the problem it is worthwhile quoting again from Mott (1984). 'About 200 million people are infected with schistosome parasites: those who get heavy infections, especially children, are in danger of severe disease, disability or death. Meanwhile, schistosomiasis represents a constant threat to as many as 600 million people as they perform activities related to water.'

It would not be appropriate to discuss the disease in detail at this stage of the seminar. This is a job best left to the experts. What should be indicated is the way we have actually tackled the project.

As a first step we undertook a literature review on schistosomiasis and its control, Deacon (1983). This review paid particular attention to the types of engineering measures that can be built into irrigation schemes, in an attempt to reduce the risk of infection. The review concluded that there was a need for quantitative information to assist designers of irrigation schemes. Whilst demonstrating that strict guidelines for design engineers could not yet be developed, the literature examined showed a strong need for further research, following design and construction, so that information on the impact of particular measures could be obtained.

Following this review, it was decided that if a project were to be set up it should focus on African irrigation and particularly on small-scale irrigation schemes which are probably going to increase in number in response to the needs of rural populations.

The choice of small-scale, small holder irrigation schemes was made for the following reasons, Bolton (1984):-

'Firstly, large commercial schemes, because of their economic importance, have generally been selected by those undertaking research into schistosomiasis to the neglect of the smaller schemes. Secondly, in many cases small schemes introduce relatively minor modifications to the environment and, because the changes brought about are less dramatic than with larger schemes, there remain many facets of the interaction between the design of such schemes and the prevalence of schistosomiasis in the human population which are poorly understood. Thirdly, the management of small schemes is generally undertaken by local groups of farmers with few supporting services. Since it may be difficult for such groups to maintain ongoing programmes of maintenance and control, especially those involving substantial costs for imported chemicals, it is particularly necessary for suitable methods of control to be introduced to small-scale schemes at the design stage. Finally, at any one time, there are likely to be far more small schemes being designed and built than large schemes. As a result small schemes provide more opportunities for research workers to introduce and evaluate chosen methods of control.

'Zimbabwe was selected as the initial area of investigation for three reasons. Firstly, there are over seventy established small-scale schemes in the country many of which have undergone or are undergoing rehabilitation. Moreover, a considerable increase in the number of small-scale irrigation schemes over the next few years has been proposed. Secondly, the country provides a fairly wide range of climatic and ecological conditions which produce marked variations in the "back-ground" prevalence of schistosomiasis over the country. Thirdly, general awareness of the importance of the disease is high. In particular, there is an existing institution, the Blair Research Laboratory, which was established over thirty years ago for the purpose of undertaking research into this disease.'

Preliminary discussions were held in Zimbabwe in June 1983 and February/March 1984 between senior members of the ODU, the Department of Rural Development (DERUDE) and the Blair Research Laboratory. Following these discussions, and a series of site visits, a broad programme of collaborative research was proposed by July 1984. The resettlement scheme at Mushandike, Masvingo Province, was chosen as a suitable location for the project.

In recognition of the complex nature of the problems under study it was proposed that a small, ad hoc group of advisers in the UK should examine the research proposal and provide guidance during the course of the investigations. Apart from the project officers at ODU the group currently has representatives from ODA, the Institute of Irrigation Studies at the University of Southampton and the Liverpool School of Tropical Medicine.

Approval for the research proposals was received, from all parties involved, by early 1985 and the study commenced in March 1985 with an irrigation design engineer being seconded to the Department of Rural Development. The task of the design engineer was to assist the officers in DERUDE to design the rehabilitation of the first phase of the Mushandike scheme incorporating features into the design to minimise the spread of infection; for example, maintaining sufficiently high velocities in the canals, minimising areas of standing water and reducing points of human contact with irrigation and drainage water. A discussion note was prepared early in this study setting out the criteria proposed by ODU for the design and operation of the scheme. The discussions resulting from this note were most beneficial in determining how the scheme should be designed and how the water scheduled during operation. A later presentation will discuss the design criteria and how and why they were subsequently modified in the light of discussions and experience in Zimbabwe.

The main collaborators in this project were originally the Department of Rural Development and the Blair Research Laboratory. DERUDE was to be responsible for the provision of a senior irrigation engineer and for the design and construction of the irrigation scheme. Our design engineer was based in the offices of DERUDE in Masvingo. The Blair Research Laboratory was to be responsible for surveys of snails and of the prevalence and intensity of infection both before, and at regular intervals after, irrigation starts in order to monitor how effective the design measures have been. In view of the fact that the Blair Research Laboratory required extra staff to undertake the proposed work a special contract was negotiated which enables ODU to support the extra technicians required during the monitoring phase of the project.

Reorganisations within the Government of Zimbabwe in late 1985 resulted in an Irrigation Division being created within the Department of Agricultural, Technical and Extension Services (AGRITEX). Many of the personnel from the Irrigation Branch of DERUDE transferred to AGRITEX who are now our collaborators on this project. Other responsibilities and staff from DERUDE were transferred to the Ministry of Local Government who will be responsible for the project finance since the irrigation scheme is part of a larger resettlement scheme being funded by the African Development Bank.

Whilst our two main collaborators are now AGRITEX and the Blair Research Laboratory we recognised at an early stage that other departments of the Ministries of Agriculture, Water Development, Finance, Local Government, Housing and Health, as well as community councils and committees at local and district levels, should have an input to our design proposals. The purpose of this seminar is to keep all interested parties informed as to our proposals and findings. We hope that the discussion generated will also help all of us appreciate the problems and constraints on such a project.

Before concluding it would be useful to list the main steps so far achieved. Progress has been slower than originally envisaged though this has enabled us to take proper account of the many different factors and viewpoints necessary in designing and operating a small holder scheme.

Table 1.1 shows the main stages in establishing the project and preparing the first designs.

1.6 Conclusions

During the rest of this seminar more details will be presented on the design problems and how they were overcome and how we believe the scheme should be operated to obtain the best from the design. What we need to know from those people who are charged with the responsibility of actually running the irrigation scheme is can the scheme be operated according to design? We hope that discussions will be wide ranging and cover the non-engineering aspects as well. We discovered early in the design process that constraints such as bore hole locations, village locations, soil depth and the rate of construction and implementation all have a major impact on the design adopted.

Incorporation of features to minimise the spread of schistosomiasis at the design stage is our main objective. However, the task cannot be left entirely to the design engineer. Views of other professionals need to be considered if schemes like Mushandike are to be successful and healthy. This seminar has, therefore, been convened to widen the discussion on how best to design and operate irrigation for schistosomiasis control.

1.7 References

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2. Deacon N H G (1983). A review of the literature on schistosomiasis and its control. HR Technical Note OD/TN3, September 1983.

3. Jewsbury J M (1984). Small scale irrigation projects and their implications for health. African Regional Symposium on Small Holder Irrigation, Harare, September 1984.

4. Mott K E (1984). Schistosomiasis : new goals. World Health, December 1984.

TABLE 1.1 Timetable for the implementation of the Mushandike research project:

June 1983 and February 1984	Preliminary discussions and site visits
June/July 1984	Original research proposal revised and submitted. Mushandike site chosen
August 1984	Control measures and monitoring programme discussed with Blair Research Laboratory
October 1984	Preliminary survey of existing population at Mushandike undertaken by Blair Research Laboratory
November 1984	Revised programme for monitoring work drawn up by Blair Research Laboratory and their collaboration approved by Ministry of Health
January 1985	Authorisation received by DERUDE for their collaboration. Draft design criteria drawn up by ODU
February 1985	Design criteria discussed in Zimbabwe
March 1985	Following the above discussions, criteria revised. Design engineer started attachment to DERUDE
May and July 1985	Liaison visits by ODU project officer
September 1985	Design of first 60ha block completed (Misty Vale). Construction team commenced work at Misty Vale. Two laboratory technicians recruited by Blair Research Laboratory to undertake field work
October 1985	Two design engineers from ODU attached to DERUDE to complete remaining 250ha for the Phase 1 of the scheme. Irrigation specialist at the AGRITEX office in Masvingo appointed as counterpart to receive training in order to undertake design work for Phase II
April 1986	Designs for Phase I completed and handed over
June 1986	First irrigation commenced at Misty Vale

2 THE IMPORTANCE OF SCHISTOSOMIASIS IN ZIMBABWE WITH PARTICULAR REFERENCE TO IRRIGATION SCHEMES

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2.1 What is schistosomiasis?

As this paper is meant to set the scene, as it were, I think it is best to make sure that we are all starting from the same point by giving a brief recapitulation of the mode of transmission of schistosomiasis, or bilharzia, as it is often known in this country.

There are two kinds of bilharzia in Zimbabwe, the bowel form called Schistosoma mansoni, and the bladder form called S.haematobium. The general life cycle differs only slightly between these two species although sometimes these differences are very important. For the purposes of an introduction I shall give you an overview of the life cycle which is applicable to both species (Fig 2.1).

The adult schistosome worms live in the blood vessels of man usually around the gut or the bladder. The worms themselves are not very important in producing the disease; it is the accumulation of the eggs produced which gives rise to most of the symptoms of schistosomiasis. Some of the eggs produced by the worms pass through the gut or bladder wall and thus to the outside in the stool or urine. Mature eggs will hatch if they reach water and the young stages produced (miracidia) search for the next host which is the snail. After penetrating the snail a cycle of asexual reproduction takes place which results in the production of thousands of cercariae from one miracidium. These cercariae are released into the water by the snail where they search for the next host which is man. On penetrating human skin the cercariae rapidly change into juvenile worms and move through several parts of the body before finally settling (usually) in the blood vessels of the gut or bladder reaching maturity and producing eggs about 6 weeks after infection. The average life span of schistosome worms is about 4-5 years and they produce about 200-300 eggs per day.

2.2 Why is schistosomiasis important?

Schistosomiasis can have severe effects on man resulting in paralysis or death but more commonly it is believed to be a debilitating disease which reduces the capacity for work, increases susceptibility to other infections, exacerbates malnutrition and, after long periods of infection, results in a greater risk of bladder cancer in middle age. The most obvious symptom to the rural infected population is the presence of blood in the urine which is typical of *S.haematobium*. *S.mansoni* infection may result in the presence of blood in the stool and diarrhoea.

2.3 What is the situation in Zimbabwe?

The distribution of schistosomiasis in Zimbabwe is shown in Figures 2.2 and 2.3 (Taylor & Makura, 1985). The north-east of the country has the greatest prevalence of schistosomiasis in the children and this is ascribed mainly to the higher rainfall which results in even small streams being perennial. The midlands and the south-east of the country are moderately affected with schistosomiasis whilst the lowest levels of infection are found in the drier western regions. It is, however, difficult to generalize as far as schistosomiasis is concerned as the transmission of the disease is very focal and greatly dependent upon the amount and type of water contact. High frequency of water contact increases the risk of contracting, and also spreading, schistosomiasis and thus, in areas where there is a low overall prevalence of the disease, there may be isolated foci, usually associated with a dam or river, where there is a very high infection rate. This focal nature of the transmission of schistosomiasis means not only that it is very difficult to generalize on the importance of the disease in an area but also that any activity which increases the amount of surface water available or the amount of water contact activity is almost certain to increase the risk of schistosomiasis. This is where irrigation schemes become of significance.

The age groups affected by schistosomiasis are as shown in Figure 2.4. It is mainly the school children who are infected and it is also these children who have the heaviest infections. The decline in infection in older age groups is believed to be mainly due to increasing immunity but decreased water contact probably also plays some role. It has been shown by Clarke (1966) that in areas where transmission is intense this age prevalence curve may be shifted to the left with a peak in the younger age groups. Overall the general shape of the curve does not change much from area to area but in areas of higher or lower transmission it is shifted up or down.

2.4 Why are irrigation schemes important?

Irrigation schemes, both private and governmental, are common in Zimbabwe and the long-term plans for the development of rural areas include the development of many more irrigation systems. Due to the water conservation methods needed to make water available for crops throughout the year the main impact of an irrigation scheme in this country is that, by regulating the rate at which water is used, it prevents the usual cycle of wet and dry seasons. The dry season in much of the country results in many streams and rivers drying up at some time of the year and this is generally fatal for snails. As a result, many seasonally dry rivers do not even have snails in them at any time of year unless there is colonisation from a dam higher upstream or from bird carriage. The vector of urinary bilharzia *Bulinus globosus* can survive short periods of drought under favourable conditions but the population certainly suffers a severe setback. The vector of intestinal schistosomiasis, *Biomphalaria pfeifferi*, can only survive in permanent water and so the transmission of *S.mansoni* is likely to be most enhanced by conservation of water. An irrigation scheme evens out some of the seasonal differences in rainfall and, in some cases, allows small streams and rivers to become perennial where previously they were seasonally dry. These drainage lines are believed to be very important for transmission of schistosomiasis in irrigation systems. From the supply side, water has to be stored during the rainy season, usually in a large dam, and then supplied to the fields throughout the year, usually through a system of night storage dams and canals. All of these may now present a permanent waterbody where there was none before and, if the conditions are right, they are rapidly colonised by snails.

We now come to the human factor. Labour for new irrigation schemes, whether of public or private enterprise, may be recruited from any part of the country. This is particularly the case with large schemes where considerable manpower is required. People moving onto irrigation schemes from other areas, and even from nearby areas, may have had little exposure to schistosomiasis due to living in a previously dry environment or a town. They can be very vulnerable to infection with schistosomiasis and react as do non immunes by developing fairly severe symptoms after only a light exposure. The resulting morbidity in such a population may have an adverse effect on the economy of the irrigation scheme as well, of course, as on the people themselves. For people dependent upon agriculture the development of new irrigation schemes is of considerable benefit to them in terms of crop production and its far reaching ramifications on health and wealth. However in an irrigation system they have to manage the water on their fields and they live in villages which are close by. Thus they have ready access to dams, canals and drains. *Any* restriction on sanitation facilities and piped water supplies has the logical result that people will make use of their surrounding resources: hence washing is done in canals or dams, excretion is carried out in the relative protection of a deep drain and recreational activities such as swimming and fishing take place. The situation thus fulfils all the requirements for excellent schistosomiasis transmission and that is exactly what happens in many cases.

2.5 What do we know about schistosomiasis on irrigation schemes in Zimbabwe?

Clarke (1966) gave a report on the prevalence of schistosomiasis in several irrigation schemes in various parts of the country and, not surprisingly, showed that schistosomiasis was very common on these schemes. He felt that it was a logical expectation that incidence, prevalence and intensity of infections of both S.mansoni and S.haematobium would increase dramatically due to three factors:

(a) the stability and permanence of water bodies which, due to lack of seasonal flooding and seasonal drought, allow the year round maintenance of relatively stable populations of Bulinus globosus and Biomphalaria pfeifferi;

(b) the high temperatures pertaining in the lowlying areas of the country which allow year round transmission; and

(c) the high density of human settlement which characterises the intensified agricultural output of irrigation systems.

Actual figures for the changes in prevalence which occur with the development of an irrigation scheme are generally not available in Zimbabwe and even in other parts of the world attention has focussed on large irrigation schemes with very little work carried out on small schemes which, in fact, probably make up the bulk of the irrigation development. In Zimbabwe, advice has been given to the Agricultural and Rural Development Authority, (ARDA, formerly TILCOR) for the control of schistosomiasis on most of its irrigation schemes for the past 20 years but very little information is available on the prevalence of schistosomiasis on these schemes. Evans (1983) and Shiff et al (1973) reported on the schistosomiasis problem in the large irrigation schemes in the south-east of the country and the high prevalence in the children. Unfortunately no pre-implementation data were available for comparison as most of the labour came from all parts of Zimbabwe and Malawi. A considerable amount of data is available for the large irrigation schemes of the Sudan (the Gezira) and Egypt but the most notable point about these schemes is the vast amount of money that has been spent over the years in trying to control schistosomiasis with relatively little success until the newer drugs came onto the market for treatment.

2.6 What control measures have been undertaken?

Shiff et al (1973) and Evans (1983) report on the implementation of schistosomiasis control on the large Hippo Valley and Triangle systems and the impact of this on transmission. The control, which works out at a cost of $1-1.5 per capita, successfully controls schistosomiasis to the level of the surrounding population from previously very high levels, in excess of 60% for both S.mansoni and S.haematobium. The cost of schistosomiasis control in established systems can be very high as shown by Jobin (1979) where costs ranged from about $1 per capita in Brazil to $6 per capita per annum in Egypt. This was using snail control alone; inclusion of treatment costs or devegetation in a programme would enhance the figures even more.

It is preferable to build in schistosomiasis control measures to the irrigation scheme in the design phase rather than face recurrent costs for the life of the scheme. To this end there have been various recommendations on the control of schistosomiasis in irrigation schemes but one of the simplest and most easily readable for the laymen or engineer is that by Ball and Pugh (1971). The general principles for control of schistosomiasis which may be implemented during the design of an irrigation system are very simple once an understanding of the transmission cycle is achieved; they are, to reduce the amount of permanent water to the minimum in all structures of the system, to allow for a regular period of drying out of canals wherever possible, to build dams of the greatest volume to surface area ratio, and to reduce the necessity of human water contact as much as possible by ensuring there is adequate sanitation and access to household water supplies.

We can advise on control measures for schistosomiasis in existing irrigation schemes and I have already stated that we do this. However, it is regularly seen that the operational costs of both private and public systems are closely related to the financial viability of that system. Schemes that are run with only marginal profits will not willingly spend money on molluscicides for schistosomiasis control and expect the Ministry of Health to be responsible for the cost of treatment. In fact, as schistosomiasis can be considered to be an occupational disease in this setting it is arguably the responsibility of the owners of the scheme to look after the welfare of their workforce. The continually rising costs of chemicals for snail control and drugs for treatment make it imperative that control measures are introduced at the design stage rather than after implementation. Very few water development projects, and then only the really large dams, are referred to the Ministry of Health prior to their implementation. Even these plans are referred at such an advanced stage that to introduce design modifications for schistosomiasis control is not then acceptable. Certainly no designs for small holder irrigation schemes have ever been submitted to the Ministry of Health for comment to my knowledge. For the maximum advantage of our irrigation development in this country we should be sure that we are implementing designs which not only have a sound agricultural input but also have a sound health input and will not be endangering the health of our people. A healthy population profits best from the opportunity to work.

This seminar, in discussing the schistosomiasis control programme at Mushandike, should serve to familiarise you with the purpose of the project and elicit your continued support but I also hope that we in the health sector will better understand the constraints faced in designing irrigation systems. Schistosomiasis is a largely avoidable health risk and, in irrigation schemes under development, I hope that through our continued cooperation we can demonstrate that this is true.

2.7 References

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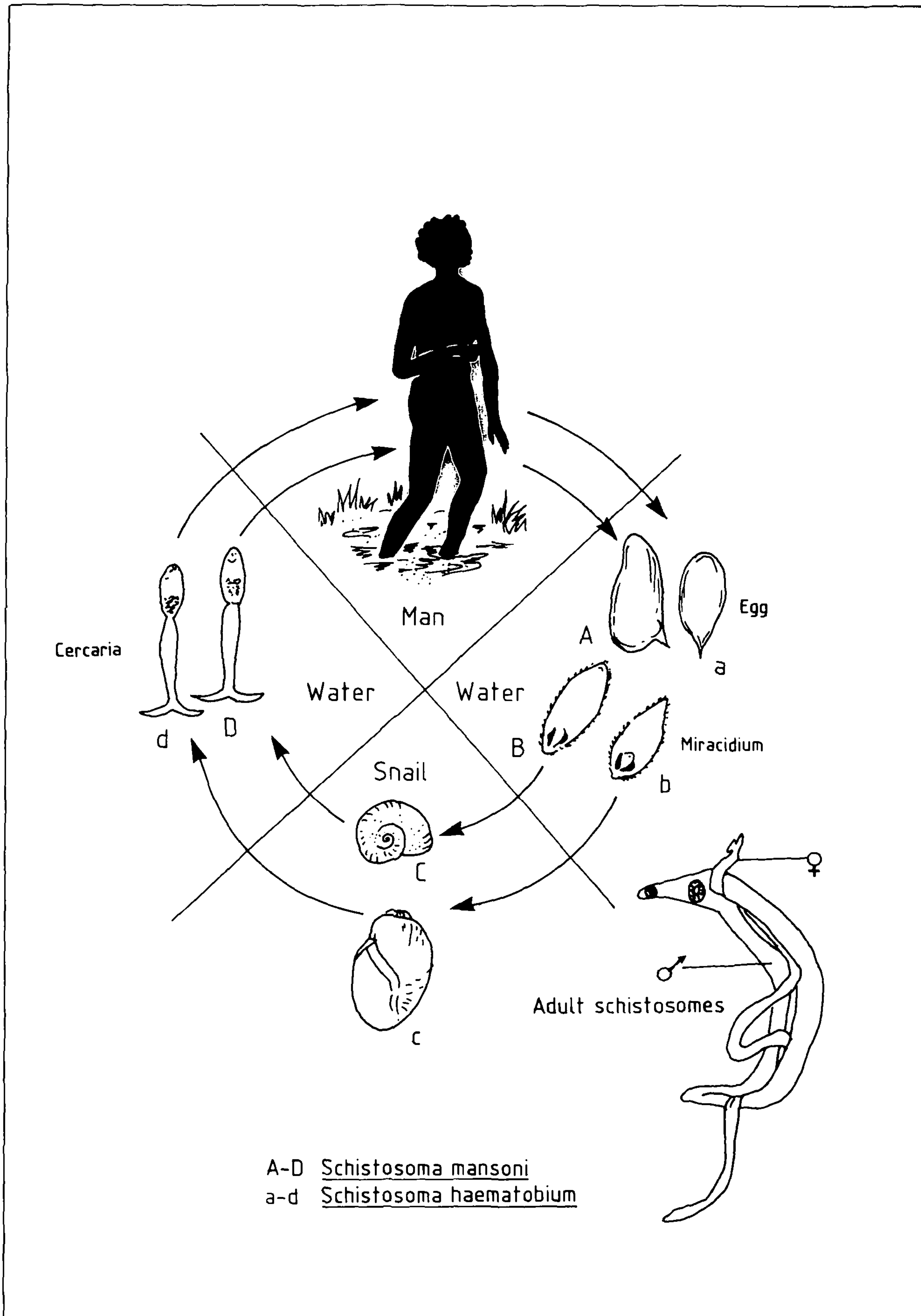

Fig 2.1 Life cycle of schistosomes

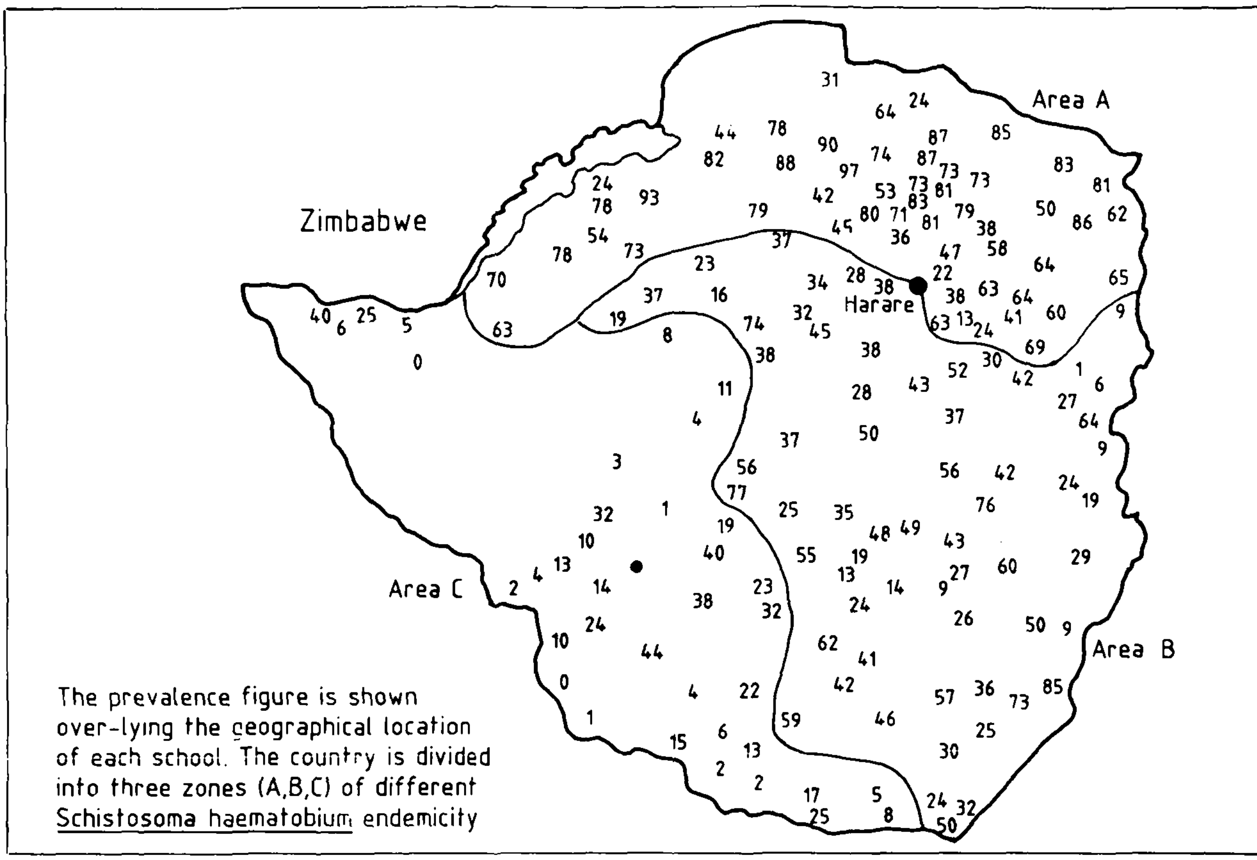

Fig 2.2 Percentage of 8 to 10 year old children with Schistosoma haematobium at each school sampled

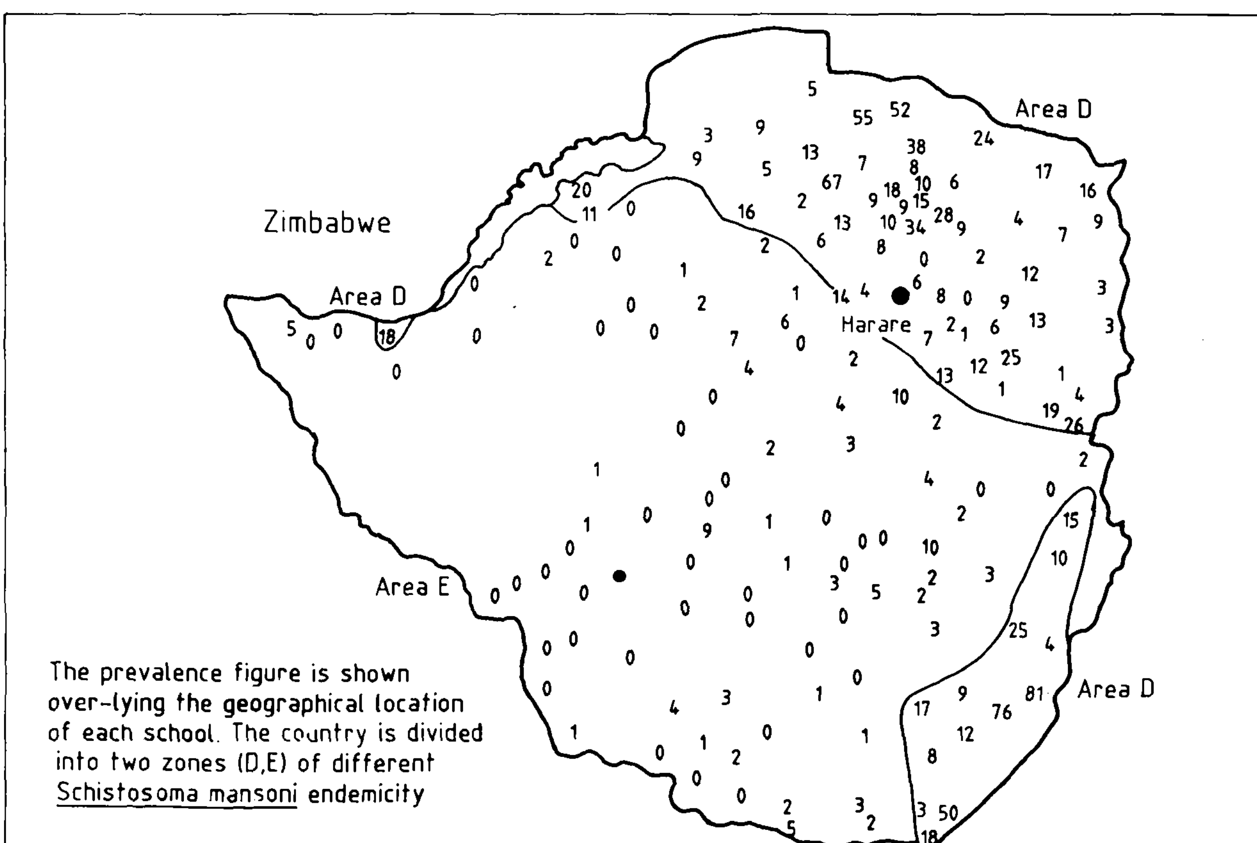

Fig 2.3 Percentage of 8 to 10 year old children with Schistosoma mansoni at each school sampled

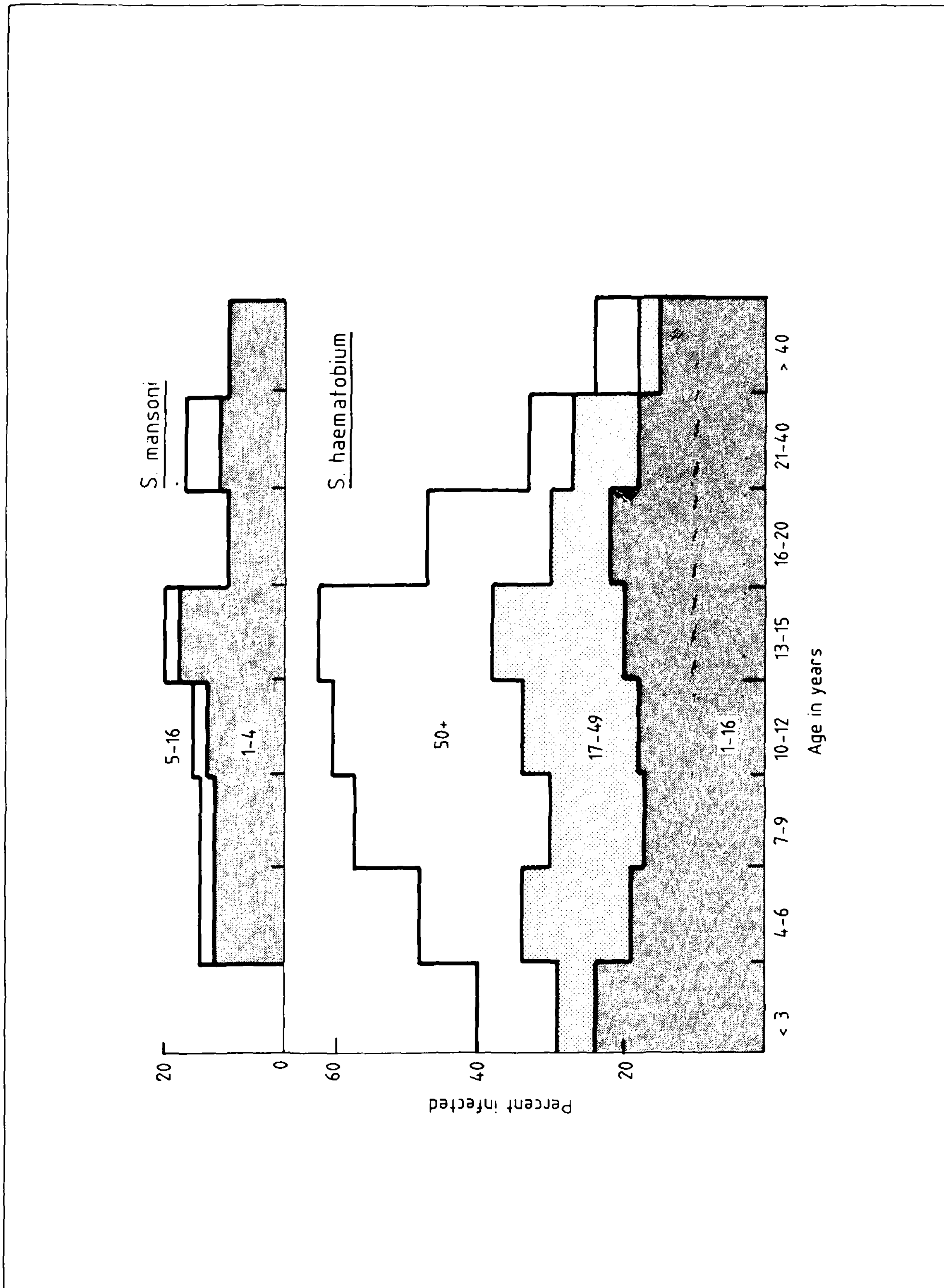

Fig 2.4 Age prevalence of Schistosoma haematobium (eggs/10ml urine) and S. mansoni (eggs/kato slide) for Madziva 1985

3 BACKGROUND TO THE MUSHANDIKE IRRIGATION SCHEME

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3.1 Introduction

The development of the Mushandike Irrigation Scheme is being undertaken by the Government to provide irrigated land to small farmers from the communal lands of Masvingo Province. The major aim is to turn the farmers into full-time irrigators by providing enough land per farmer which is manageable under the existing constraints of lack of family labour as well as the non-availability of a high degree of technology among the farmers. This development effort is being undertaken by the Departments of Agritex and Rural Development in collaboration with Hydraulics Research, Wallingford, United Kingdom and the Blair Research Laboratory of the Ministry of Health. Funding for development was secured from the African Development Bank (AfDB) and the Government of Zimbabwe. This paper will review the background to the Mushandike Irrigation Scheme within the context of the resettlement programme and make suggestions for further collaboration after the project implementation stage.

3.2 Pre-independence development

3.2.1 Mushandike Dam

In 1939, a dam was completed on the Mushandike River, see Table 3.1. The aim of this development was to create what is known as the Mushandike Recreational Park as well as provide irrigation water for the Mushandike Intensive Conservation Area downstream of the dam. The farms were in a low rainfall area and irrigation was justified to ensure optimum crop maturity as well as production in the winter months. The rainfall here varies between 450-600mm and the area is characterised by severe mid season droughts which make crop production risky. Traditionally, therefore, this area was only suitable for livestock production which could hardly be sustained due to the low rainfall and erratic distribution. The dam made it possible for both summer supplementary and winter irrigation to be undertaken in this otherwise very dry area. The main crops grown included cotton, winter wheat, barley, oriental tobacco and also vegetables.

Successive cropping of winter wheat created a problem of wild oats forcing some farmers to abandon wheat for some time.

3.2.2 Mushandike Intensive Conservation Area - Irrigation

With inadequate rainfall that had been poorly distributed, the Mushandike Dam introduced a new dimension in the farming activities of the farmers served by the canal. Water was allocated by the water bailiff on a demand basis. The full flow of the canal was given to two or three farmers for the day, depending on demand, and the farmers stored most of the water in a number of night storage dams on their farms. The night storage dams then allowed them to have water on the other days that they were not due water. This system allowed a large area on each farm to be flood-irrigated and, as the number of farm gate outlets was restricted to one or two per farm, it meant that water was not a limiting factor. This is further supported by the fact that irrigation was then introduced into a number of marginal areas - just because the water was there. Further evidence of this lies in the Soil Survey Report produced by the Department of Research and Specialist Services which indicated that parts of the previously irrigated land had very marginal soils for irrigation. The system of irrigation employed was flooding large basins - there were no infield canals as such except temporary ones that were formed as and when required. In some farms like Trebah, a system of pipe turn-outs was employed. It would appear that the individual farm schemes were farmer designed and tended to be operated in a variety of ways depending on the crop that was on the ground or the amount of water that was available to the farmer. Judging by the multiplicity of night storage dams throughout the scheme, one is given the impression that there was more water available than land to which it could be channelled and used for production.

3.2.3 Crop production enterprises

A point has already been made in 3.2.1 that the area is dry with little rainfall. The crops that were produced by the farmers included cotton, sunflowers, wheat, barley and to a lesser extent maize and oriental tobacco. Irrigation made it possible to supplement the inadequate rainfall in summer and fully irrigate crops like wheat or barley in winter.

The production enterprise was largely cash oriented but limitations imposed by the agro-ecological conditions often entailed that yields were low even under irrigation conditions. Before the current project, one is given an impression that water management was not of particular importance and methods employed tended to be both wasteful and unorthodox. Semi-skilled labour was used for irrigation and the farmers decided on the irrigation schedules themselves in the absence of a reference meteorological station nearby. The reference station for Mushandike is either Masvingo or Makoholi and both areas have micro-climatic characteristics which are different from conditions at Mushandike. However, despite these limitations, a reasonable level of success was obtained with crops such as wheat, cotton and soyabeans.

3.2.4 The run-up to independence

The Mushandike ICA is bounded by the Chivi Communal Lands to the north-west, west and south-west, while the Mushawasha small-scale farming area is to the south. This situation tended to make the area suitable for over-running during the liberation struggle. As a result, a number of farmers left their farms in fear and took refuge in the urban areas leaving the farms abandoned and subject to possible plundering and vandalisation of buildings by people from the communal areas. Production in the areas between 1977 and 1979 was heavily affected and the few farm labourers left there carried out some subsistence farming, but otherwise the irrigation infrastructure was left unmaintained. The livestock was moved to relatively secure areas and a number of cattle from communal areas wandered throughout the farms often causing irrepairable damage to the irrigation infrastructure. The electricity network was also abandoned and farmers salvaged movable items like pumps and motors from some night storage dams in their retreat.

3.3 The dawn of independence

3.3.1 Land pressure in communal areas

The Communal Areas (formerly known as Tribal Trust Lands) are characterised by poor soils and poor agricultural potential particularly in terms of cropping.

Some Communal Areas are also characterised by tremendous pressure on land, to the extent that cultivation has now been pushed into marginal areas with disasterous, and sometimes irreversible, consequences. Lack of employment opportunities in urban areas for blacks tied them to land as subsistence farmers and, as the potential in these areas was inherently low, it did not help the situation at all. In addition to the land pressure, the war of liberation had produced a number of effectively landless people who were now returning to Zimbabwe from refugee camps in Mozambique, Zambia and Tanzania. The failure of the economy to generate more employment had compounded the problem. All landless and unemployed people added to the potential land pressure.

3.3.2 Post independence agrarian reforms

The situation described in 3.3.1 above needed to be redressed. The new Government then embarked on an agrarian reform that was aimed at redressing the imbalances that existed before independence. The major imbalance was that of land holding in general and the quality of such land in particular. There was also a large number of absentee landlords who leased their land to other people but did not stay in Zimbabwe. The Government had to resettle the returning landless as well as the unemployed who wanted to start a new life on the land. At the same time, however, the Government had to abide by the provisions set in the Lancaster House Constitution. Whatever agrarian reforms had to be implemented, these had to be in keeping with what was agreed at Lancaster House in 1979.

3.3.3 The resettlement programme

Agrarian reforms after independence were largely manifest in the resettlement programme. This programme was initially spear-headed by the British and Zimbabwe Governments; other donor countries and organisations joined in later. The major objectives of the resettlement programme were to resettle the landless peasants on previous commercial land so that they could produce for themselves as well as contribute to the gross domestic product. It was hoped that this programme would go a long way towards satisfying land hunger among the peasant population. A number of models were devised as follows:

Model A: Individual family holdings of 5ha nett with 0.1ha as a homestead. There was communal grazing and the number of livestock units per family was based on the assessed carrying capacity of the area set aside for grazing.

Model B: Agricultural collective farming. Members were encouraged to farm collectively. This model was applied where the farm infrastructural development was high - particularly where irrigation facilities still existed.

Model C: This is basically a state farm with outgrowers who derive essential services such as land preparation, harvesting, input supply and marketing from the core-estate in return for a component of their labour. The principle was based on the fact that the two would complement each other's activities for mutual gain and benefit.

The framework of the resettlement models, therefore, was aimed at affording the best form of land use based on available infrastructure and resources. One fundamental aim behind the resettlement exercise was to ensure that the productivity levels of the farms was maintained in the first instance and even improved in the future. The newly settled families had to produce to the same degree if not more than the previous farmer.

3.3.4 Land acquisition for resettlement

The land for the resettlement exercise was acquired on a willing seller willing buyer basis. Initially Government took up all abandoned land that was offered to it for sale; however, it soon became apparent that not all land could be settled on the basis of the models indicated above. In provinces such as Matabeleland South, consideration had to be given to a ranching model (Model D). It was entirely by coincidence that, to begin with, land was available in large contiguous blocks - an aspect which greatly facilitated the planning of this programme.

As all farmers were free to make an offer, there became a situation whereby isolated farms were bought and these could not satisfy some of the planning parameters (3.4.2) set out in the policies and procedures document.

3.4 Planning for development

3.4.1 The Mushandike Irrigation Project

The Mushandike Irrigation Project was planned within the context of the resettlement programme. One of the major constraints was that, until the Mushandike scheme was hatched, there had been no prior consideration for irrigation under the Model A basis. Whatever irrigation had been planned and implemented was under the Agricultural Collectives (Model B). This thus necessitated a new set of planning parameters and a departure from the modular approach to resettlement planning. A new set of criteria based on an irrigation model had to be established relating particularly to the size of holding which had to be less than under dryland conditions. A new set of economic assumptions had to be formed and this was not merely a resettlement exercise, economic viability had to be established as well. In the case of Mushandike it was not possible to settle people on the existing irrigation developments which lent themselves to large scale operation. These new settlers had to be small holders. Replanning and redesign of the schemes therefore became necessary.

3.4.2 Planning parameters

As no other resettlement scheme had been settled on an irrigation model before, the basis for planning at Mushandike had either to be evolved or based on existing small-scale irrigation schemes in communal lands. The basic problem with communal small-scale irrigation schemes was that they lacked financial viability and most of them had been set up initially as food security schemes or for food self-sufficiency in areas where the Government would otherwise have had to provide drought relief. The size of holding in communal area small-scale irrigation schemes was so variable - from as little as 0.1ha (or sometimes less) to as much as 1.6ha in some schemes. Simply taking an average was not going to be representative enough. The size of holding also has a bearing on types of crops to be grown and, ultimately, on the gross incomes given the need to rotate for crops to control crop disease.

This meant that smaller land holdings precluded the production of crops such as cotton and wheat and favoured crops like vegetables which, in most cases, did not have a regular market. Given the above constraints the planning parameters at Mushandike took the following form.

(a) The basic unit of land for design purposes was set at 0.5ha.

(b) The total land holding for a family would be 1.5ha held either as two units of 1ha and 0.5ha in different places or as three units of 0.5ha in different places.

(c) The holding of units in different locations and not in a contiguous manner would facilitate crop rotation and block farming and make disease control easier.

(d) The holding of units in different blocks by a family would also facilitate water management and ensure that the family was more fully occupied in irrigation than would be the case if the 1.5ha holding was in one block and had to take water in one day.

(e) These parameters were subject to the realisation that distances between the different units had to be minimal so that the farm families would not be unduly inconvenienced.

(f) As a standard practice, ventilated pit latrines were to be provided in-field.

(g) The social need of the farmers had to be catered for. Their desire to keep poultry and small stock had to be considered as part and parcel of the project.

The fact that a larger number of small farmers was going to be involved would necessitate a change in the layout of the scheme and was going to increase the number of distribution canals - also higher distribution losses were possibly going to be encountered. This situation demanded that the amount of water that gets to field edge had to be maximised and hence a proposal to line the main canal was made.

3.4.3 Redevelopment finance

The planning parameters depended largely on the amount of money that would be available for development. At the time planning was taking place, the land had already been acquired by Government at a total cost of Z$830 000 (including some farms on Mushandike dry land), see Tables 3.2 and 3.3. As the amount of money available for development from Government was limited, assistance was sought from the African Development Bank (AfDB). At the time the AfDB became involved, the need for an irrigation oriented resettlement project at Mushandike had already been identified. However, Mushandike alone was unattractive to the AfDB; they were looking at a wider project of which Mushandike was only going to be part. Accordingly, an identification mission was sent to the country from the Food and Agriculture Organisation Investment Centre and they used most of the work already done by Government officials to include the Mushandike Irrigation Scheme in an expanded project encompassing, in addition, Wenimbe, Macheke ICA, Masasa and Mushandike dryland. The expanded version of the project is what is currently under implementation.

The Food and Agriculture Organisation Investment Centre's recommendations included works that had to be carried out by Government departments. Among this work was the design of the irrigation layout and subsequent construction of the in-field works including canal lining of the main, secondary and tertiary systems.

3.4.5 Collaboration with Hydraulics Research and Blair Research Laboratory

At about the time when the AfDB was appraising the project, a collaborative effort between Hydraulics Research (HR) and DERUDE was being pursued. The two were already involved in a joint water management study at Nyanyadzi. It was decided to bring in the Ministry of Health's Blair Research Laboratory as the focus of investigation was going to touch on health related aspects; work particularly under the ambit of Blair Research.

It was decided that design aspects would be carried out jointly between Hydraulics Research and DERUDE while the investigative approach and project design for schistosomiasis control would be a joint exercise between HR and Blair Research. The collaboration has yielded the following results.

- A design for Misty Vale has been done by HR and implemented on the ground by DERUDE.

- A design note to assist in further irrigation designs by Agritex staff has been produced.

- Project preparations for schistosomiasis monitoring and control are now in progress with Blair Research.

It should be borne in mind that work is continuing and that no results are as yet available for presentation.

3.4.6 Project implementation

The project is being implemented by development teams with supervision from Agritex. These development teams have had experience in this type of work at Nyamaropa, Nyanyadzi and Exchange Irrigation Schemes before their current task. Development is based on force account work where the maximum possible use is made of semi-skilled labour, local resources and appropriate technology. This is part of the development philosophy which aims to keep costs of development within reasonable limits. The pace of development is likely to be determined by the availability of resources, particularly those derived directly from the Government. It is anticipated that complete development will have taken place in the next three years. Meanwhile, project monitoring for schistosomiasis control will run parallel with the construction of in-field works in other areas.

3.4.7 The future of the collaborative efforts

The Mushandike schistosomiasis control project is really in its infant days. By the time reliable results start being reported, it is anticipated that the scheme will have been in operation for over 5 years. During this period, it is expected that co-operation and collaboration between and among the agencies involved will continue to be strengthened.

It is also hoped that, even before the current project is concluded, valuable lessons will have been learnt particularly on design aspects and that these lessons will be adopted into the general practices of the Department of Agritex whenever irrigation schemes are designed. It is too soon yet to draw firm conclusions on the replicability of current efforts to other schemes but so far the training aspect has been invaluable to staff.

3.5 Conclusion

It is always, desirable that irrigation development should be sustained by the beneficiaries in the post-implementation stage. At the same time it is obvious that, for the people to sustain this development, the effects of debilitating diseases particularly within the project, or those that can be brought about by the project, need to be minimised or more preferably eliminated completely. This is what the collaborative research efforts on Mushandike Irrigation Scheme will try to achieve. Productivity is increased when people work hard. The irrigation practitioners and health scientists should make it possible that the health of farmers is maintained at a reasonably high level for the production to take place.

Table 3.1

MUSHANDIKE DAM CHARACTERISTICS

Catchment area	$324km^2$
Mean annual run-off	58.46mm
Full capacity	$37.19 \times 10^6m^3$

RESERVOIR YIELDS

At 10% risk level	$9.35 \times 10^6m^3$
At 20% risk level	$11.50 \times 10^6m^3$

Table 3.2: Land acquisition costs

Name of Farm	Area purchased (ha)	Amount (Z$ 000)
Avondale	2055	70
Invicta	2033	85
Montevideo	2733	70
Stanhope	1029	69
Enterprise of Stephanie	644	72
Lochiel	1395	68
Trebah	837	70
Charlton Park	541	58
Misty Vale	899	45
Ashcroft	780	46
Umshandige	561	40
Bethinia (C. Upcott.)	179	48
Excelsior	3619	80
A & B of Upcott	46	9
TOTAL	17351	830

Table 3.3: Areas suitable for irrigation

	Area covered (ha)		Proposed scheme (ha)		
Farm	Total cleared area	By soil survey 1:12.500 map	1:12.500 layout	Excluded from soil survey	Included in soil survey
Excelsior	265	-	-	-	-
Avondale	90	118	74	38	36
Invicta	225	102	136a'	53a'	83
Ashcroft	165	78	123b'	56b'	67
Misty Vale	85	51	50	-	50
Umshandige	130	71	65	10	55
Charton Park	80	47	53	-	53
Trebah	110	91	87	-	87
TOTAL	1150	558	588	157	431

a' includes 13ha 'uncleared irrigable area'
b' includes 48ha 'uncleared irrigable area'

4 DESIGN OF THE MUSHANDIKE IRRIGATION SCHEME

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4.1 Introduction

The control of schistosomiasis using measures which change the physical characteristics of an irrigation scheme is not a new concept. Such measures are generally referred to as "engineering" or "environmental" control. The literature contains many references to practical steps which can be taken by engineers and planners to control this disease, see Deacon (1983). Yet their adoption by engineers in the designs for new irrigation schemes is far from widespread. Indeed, even at a pilot study or research level, there are few examples of schemes into which engineering control measures have been introduced. Part of the reason for this is that a large number of unresolved questions remain particularly with regard to the practical details of transforming general ideas about control into specific engineering designs. These questions are being addressed in our research project and are highlighted in this paper.

It is worth stressing from the start that we did not begin our study at Mushandike with a ready formula for eradicating schistosomiasis. There are no "magic" structures whose introduction can guarantee that an irrigation scheme remains free of the aquatic snail hosts of schistosomiasis. In the aquatic environment we are dealing with a complex system of interacting physical, biological and social factors. If we are to progress towards a sensible control strategy we require close collaboration between a wide variety of professions and disciplines as well as painstaking observation of the effects of any measures introduced.

The Mushandike Irrigation Scheme is unusual in the priority being given to schistosomiasis control at all stages of its design, construction and operation. Nevertheless, the project is being implemented and managed in a manner as close as possible to that of other small holder irrigation schemes in the Communal Lands in Zimbabwe. This is important because measures found to be successful in the control of schistosomiasis at Mushandike would be worthless unless they could be introduced readily to other projects. Thus, the priority which we give to schistosomiasis control at Mushandike must necessarily be tempered by the normal constraints within which such irrigation schemes are designed and built. A major part of our research project is, therefore, to assess at a practical level whether "engineering" control measures can be applied successfully within the context of small holder irrigation schemes in Zimbabwe.

Categories of constraints on irrigation design and operation include the following : physical, historical, social, institutional, political and economic. This paper goes into some detail on the first two of these but touches only briefly on the others.

Economic constraints are not discussed although they are of particular interest as the following quote from the original research proposal, Bolton (1984) shows:

'An important key to the eventual success of the research project lies in a proper understanding of the financial factors which govern project design and implementation. As yet there appear to be no absolute limits applied to project costs for such projects in Zimbabwe. The capital costs of new schemes are not charged to the farmers and only a proportion of the annual running costs are likely to be recouped from farmers through maintenance charges. It is officially recognised that the government must subsidize these irrigators as a means of increasing the production of certain food and cash crops and of providing jobs and livelihoods in depressed rural areas. Thus, although the internal rate of return is calculated in project reports, there are no guidelines on acceptable capital or running costs. The stated policy is:

> "to provide certain infrastructure within the scheme at the lowest cost possible and to provide only the essential basic facilities for farmers to establish themselves". DERUDE (1983) p 7.

'Such a policy raises difficulties in deciding acceptable levels of expenditure on schistosomiasis control works. Although the case can be made that such works are "essential" and must, therefore, be provided whatever the cost, a more realistic approach is required. At this stage only a general principle can be stated, that, as far as possible, the proposed control works must not cause a substantial increase in projects costs'.

This is a rather unsatisfactory approach but it is intended that more careful consideration of the economic aspects of the research will be undertaken in due course.

A general plan of the Mushandike Irrigation Scheme is given in Figure 4.1.

4.2 Outline of control measures

The schistosomiasis control measures being evaluated at Mushandike may be considered in two categories. The first comprises measures aimed at modifying the aquatic environment in order to inhibit snail colonisation. Such measures are closely related to the design and operation of the irrigation works. The second comprises measures aimed at reducing human contact with potentially infected water and preventing human contamination of water. Such measures are generally regarded as part of public health. Both categories are seen as important in the control of the disease.

The term 'historical' constraints in the preceding section refers to the fact that Mushandike is not a new irrigation scheme but involves the rehabilitation of an existing scheme. Although most of the in-field works and villages will be completely new, parts of the existing system will be retained. In particular, the land previously cleared and levelled for irrigation is being re-used; the main canal will be substantially unchanged, although it may be lined to reduce seepage losses; existing boreholes for domestic water supply will be utilised; and, most significant of all for disease transmission, the dispersed 'night storage reservoirs' constructed to provide farmers with control over their own supplies will be retained. The reservoirs are necessary because the total length of the main canal is 32km.

In approaching the design work for Mushandike a set of criteria has been prepared using control measures drawn from the available literature, see Bolton and Draper (1985). The criteria were discussed extensively in Zimbabwe and modified before design work began. The criteria were based around Figure 4.2 which shows the sequential steps to be followed in the design and implementation of Mushandike. Despite the fact that the schistosomiasis research was established at an early stage it can be seen from Figure 4.2 that a large number of decisions affecting the form of the irrigation scheme lie above the line denoting when schistosomiasis control criteria can begin to influence the design.

The following discussion will not follow the steps of Figure 4.2 but, rather, will group together similar types of control measure. Attention will be drawn to any changes of approach which have been introduced since the criteria were drawn up. Full details of the measures and their practical application in the design of the Mushandike scheme have been published, see Draper and Bolton (1986). That report is intended as the basis for the remaining design work to be undertaken at Mushandike.

4.3 Methods related to the irrigation works

4.3.1 Canal lining

Concrete lining of canals in small irrigation schemes in Zimbabwe is widespread and has considerable effect on snail colonisation. The snails are controlled both by high water velocities and by the ease with which canals can be dried out when not in use. If the canals and structures are properly maintained there is also less likelihood of pools of excess water and areas of swamp developing around the scheme as a result of water escaping as seepage or through breaches in the conveyance system. Finally, the use of lined canals assists in controlling water distribution thereby reducing the quantity of water flowing into the drainage system. Lined canals assist in the control of water distribution by facilitating the use of syphons by farmers to transfer water to their fields and by enabling flow measuring structures to be introduced more readily into the canal system.

At Mushandike some of the existing secondary canals are lined and it was intended that these would be repaired for use although this would not be possible in cases where their capacity is too small. A number of the existing canals are also at gradients steep enough to sustain supercritical flow. This situation is to be avoided in any canal which has control structures because a hydraulic jump will form upstream of each structure causing damage to the canal and possible overtopping of its banks. Furthermore, the design of any drop structures operating under supercritical flow requires considerable care.

In general the canals at Mushandike are designed for subcritical flow; especially those downstream of the night storage reservoirs. In the standard size of secondary canal the maximum velocity is taken as 0.85m/s with a canal gradient of 0.2%. Since the land slope is 1-2% a canal gradient of 0.2% gives rise to frequent drop structures. Despite the cost of these structures the canal cannot be steepened to reduce the number because of the danger of creating supercritical flow. If unlined canals had been used the number of drop structures would, in fact, increase because unlined canals are designed for lower velocities and, therefore, shallower gradients.

In constructing concrete lined canals two considerations are important. First, good construction is essential both in preparing the foundations and in maintaining good quality concrete. If the canal is not well constructed cracks will soon develop leading to high seepage losses and, eventually, catastrophic failure of a whole section of canal. Secondly, care must be taken to maintain a steady fall in the invert level of the canal according to design. If this is not achieved the system will not be free draining : water will collect in any hollows created.

Although concrete lining of canals is the ideal, there are several schemes in Zimbabwe where all or part of the canal system is unlined. At a future stage, research could be undertaken to determine the conditions, if any, under which unlined canals could be used without prejudice to health.

4.3.2 Drop structures

It is intended that all hydraulic structures will be designed so that the system is free draining. Drop structures are generally designed with sunken stilling basins below the drop to dissipate the energy. Engineers favour the use of sunken stilling basins because their design lends itself to theoretical treatment and, as a result, standard design procedures are readily available. Alternative methods of dissipating energy have been used but designs based on them are largely empirical.

It should be admitted that the use of sunken stilling basins at Mushandike would be unlikely to lead to snail colonisation since velocities in the concrete lined canals are high and there is strong turbulence around the drop structures. Nevertheless we are hoping to find a suitable design of free draining drop structure for two reasons:

(a) for use elsewhere in situations where snail colonisation may be a problem;

(b) because the pool of water which remains in a stilling basin when the drop structure is not in use provides an ideal breeding ground for mosquitos.

A post-graduate project at the University of Southampton has recently been completed, under our supervision, in which various designs of free draining drop structure suitable for use at Mushandike have been tested. The results will be published shortly. The most suitable structure appears to that shown in Figure 4.3. It comprises a box stilling basin of dimensions similar to those recommended for use in standard drop structure design but instead of the floor of the basin being below the invert level of the downstream canal it is at the same level. Energy dissipation is aided by insertion of three large baffle blocks in the floor of the basin. It is recommended that this design is followed in future at Mushandike. In certain circumstances the blocks may be omitted since the lateral mixing in the box section below the drop dissipates considerable energy by itself.

4.3.3 Off-take structures

The primary purpose of tertiary off-take structures is to provide for a controlled discharge into a tertiary canal for use by the farmers. The required discharge should be available for different discharges in the secondary canal and the structures should be as cheap and easy to operate as possible. In many schemes in Zimbabwe this has been achieved by placing a long weir longitudinally, diagonally or in the form of a duck-bill across the channel. Upstream, water is ponded to the level of the weir and a wide range of discharges can pass over the weir for very little change in upstream water level. By placing sluice gates in the sides of the channel upstream it is relatively simple to control the flow into one or more tertiary canals.

From a health point of view the major disadvantages of weir/sluice gate structures are that water is ponded in the upstream channel after irrigation ceases and that water generally seeps past the sluice gates leaving the tertiary canals damp when they are not in use. The first of these can be overcome by putting drain holes in the weir but these may become blocked either accidentally or intentionally, by farmers trying to maximise the flow in a particular tertiary canal. Operationally these structures are advantageous because the sluice gate need only be set once to give a selected tertiary canal discharge even if the secondary canal discharge changes. However, the opening of sluice gates must be regulated in some way to prevent farmers at the top of the scheme taking most of the water leaving little for the tail-enders.

A different type of off-take was proposed initially at Mushandike, see Figure 4.4. It comprises a sluice gate in the secondary canal just downstream of a small drop. Between the drop and sluice gate a short weir in the side of the channel passes water into a tertiary canal. Water flows below the weir crest when the gate is fully open but as the gate is progressively closed the upstream water level rises and increasing amounts of water flow over the weir into the tertiary canal. Wing walls either side of the gate are set at such a level that they act as an emergency spillway passing additional water downstream as the discharge into the tertiary canal approaches its maximum capacity.

The advantages of the structure are that it is free draining, it does not pond water in long reaches of the upstream canal and it does not allow seepage into the tertiary canal. It may also be possible to calibrate the off-take weir and so allow easy measurement of the discharge into the tertiary canal by setting a gauge plate in the wall of the structure. The disadvantages are that the discharge into the tertiary canal is rather sensitive to the gate setting, that it is only really feasible to have one tertiary canal controlled by each off-take structure and that the gate setting must be changed whenever the discharge in the secondary canal changes. In fact, the gate settings in a given secondary canal reach must be adjusted in turn starting at the downstream end of the canal.

The hydraulic performance of the gate, and a number of modifications to it, is being investigated in a laboratory flume at Wallingford. The results will be available shortly. The tests are directed towards assessing the sensitivity of the gate setting and the discharge characteristics of the weir. The question of how easy it is to operate the structure can only be answered in the field; off-take structures of this design were built on the Misty Vale block but modified duck-bill weirs are being used elsewhere at present.

4.3.4 Physical barriers

The use of physical barriers to prevent snails passing into previously uninfested reaches of canal was suggested at the outset of the research project, Bolton (1984). Their use has currently been rejected because of the practical difficulty of maintaining adequate discharges through a screen which has mesh small enough to trap juvenile snails.

4.3.5 Flow measuring structures

These are required to ensure that water distribution is carefully controlled. Many of the standard designs have a depressed invert which would retain water. The design introduced to Mushandike is a long-throated flume which lies along the same invert as the canal.

4.3.6 Drainage canals

Lining of drainage canals was earlier suggested as one possible control measure. In practice, no surface drains have been specially constructed since the steep land gradient and large areas of uncleared scrub appear to offer adequate natural drainage. This policy must be reviewed once the scheme is fully operative.

4.3.7 Night storage reservoirs

For health reasons, it is preferable to avoid storage reservoirs close to fields and villages. At Mushandike the night storage reservoirs of the existing system cannot readily be eliminated. However, several measures involving desiccation and water level fluctuations are being tried to discourage snail colonisation. Excess storage capacity is being removed. Certain key reservoirs may be divied so that one part of the storage can be closed and drained, during periods of reduced demand, allowing maximum water level fluctuations to be achieved in the other. Where irrigation blocks are supplied by several night storage reservoirs such sub-division is unnecessary provided that by-pass canals are constructed to allow dams to be used or drained at will. There is a danger that seepage cracks will develop when simple bunded storage reservoirs are dried out. However, this does not appear to be a problem at Mushandike because the clay content of the bunds is relatively low.

The precise effect on snail populations of fluctuating the water level is unknown. Occasional rapid drawdown is known to be an effective control measure by stranding snails but regular fluctuations simulated under laboratory conditions have been found to stimulate egg laying. It is, therefore, important that the snail population in the reservoirs at Mushandike are closely monitored and any differences attributable to different operating patterns noted. Complete desiccation may prove difficult unless the last of the stored water is wasted. This is because the head difference between the reservoir bed and the downstream canal is small giving very low discharges through the outlet valves as the reservoir becomes empty. Such discharges cannot readily be incorporated into the normal irrigation schedule.

At an early stage in the operation of Mushandike two important surveys must be undertaken on each night storage reservoir. First, each reservoir should be inspected to ensure that no seepage cracks have developed while it has been out of use. Secondly, the capacity of each reservoir should be surveyed so that an accurate capacity curve can be calculated and a gauge board installed to assist in its operation. Since we have tried to eliminate excess storage capacity in order to maximise the magnitude of water level fluctuations, it is essential that the bunds are built to the level shown by the engineer on the rehabilitation plans. Periodically, the bund heights will need to be checked and restored if the material has not been adequately compacted. Spillway levels have a crucial role in determining the stored volume and these should be carefully checked during construction.

In the design criteria, Bolton and Draper (1985), it was suggested that reservoirs formed on sloping land by construction of bunds on three sides only should, if possible, be removed during the rehabilitation. If this was not possible, the criteria suggested deepening these reservoirs and constructing the bund on the fourth side. In practice it has not been possible to eliminate such reservoirs without considerable extra cost and the idea of deepening them was not considered feasible because it would break through the impervious bed which had formed over the years. Such dams must be monitored for snails particularly closely. We must establish whether snails are more likely to colonise reservoirs with gently sloping banks as opposed to those with the normal bund slope of 1:2.

4.3.8 Water scheduling

Downstream of the main canal, the irrigation layout, canal sizes and structures and storage reservoirs are being designed for rotation of supply rather than for continuous flow. This will maximise the time particular canals in the system remain dry. Drains can also be allowed to dry through careful control over the water schedule and water application quantities. Short-term drying of canals and drains may not kill all aquatic snails but is likely to disrupt their breeding and colonisation.

It was originally envisaged that night storage reservoirs would be used to provide 36 hours of storage once a week so that a non-irrigation day could be allowed in the schedules. This does not now appear to be feasible during periods of peak demand without a considerable increase in the available storage capacity.

Calculation of suitable irrigation schedules to meet schistosomiasis control objectives involves a fairly complex process of trial and error. The number of field canals in operation at one time must be minimised as must the number of night storage reservoirs. In addition, there are various hydraulic constraints which must be met. Since crop water demand is changing through the season the schedules must be modified accordingly.

A technical note is in preparation, see Dube and Bolton (1986), to assist the irrigation manager in calculating the water schedule. Details are given of each stage of the calculation including preparation of capacity curves for reservoirs, discharge characteristics for canals and outlet works, suitable schedules for the rotation of supply to different tertiary canals for different irrigation intervals and curves showing water level fluctuation in the reservoirs. It is estimated that the initial calculations to prepare this information for each irrigation block would take several days but once a set of alternative schedules has been produced the day-to-day operation would not involve lengthy calculations. The manager would, of course, have to use his experience to choose the appropriate irrigation interval at each stage in crop development and decide how long irrigation should be suspended following rainfall.

A number of factors still have to be determined before a clear policy can be formulated on water scheduling. Most notably, we must determine how many farmers can irrigate simultaneously from one tertiary canal for a given size of syphon and using particular canal checks. This number should be as large as possible if we are to achieve the objective of having few tertiary canals in operation at any time.

An important aspect of the research at Mushandike will be to assess whether small holder farmers can operate schedules of this complexity. Much will depend on the management structure introduced and the adaptability of the farmers. These and a number of other important questions relating to water scheduling can only be answered by studying the scheme once irrigation begins.

4.3.9 Routine maintenance

Weeds in the irrigation system provide a suitable habitat for snails, decrease the capacity of and velocity in irrigation canals, cause deterioration of canal linings and provide protection for snails against being dislodged by high water velocities. At Mushandike, there is less need for weed clearance from canals because the concrete linings will prevent weed growth except at construction joints or in deposited silt. The night storage reservoirs, on the other hand, are likely to become heavily vegetated. Weed clearance should preferably be undertaken when the irrigation schedule allows them to be dried out so that maintenance workers are not unnecessarily exposed to infection.

Another important maintenance task is to ensure that water does not escape from the system through seepage cracks or broken structures thereby creating pools and swamps in which snails and mosquitos can breed.

4.4 Measures related to public health

The Public Health aspects of the control measures at Mushandike are covered in detail in other presentations to this seminar. However, there are a number of observations and questions which have arisen from the design work for the project which it is worth recording here and discussing in the seminar.

4.4.1 Village location

Locating villages a long distance from potentially infected water has been used as one possible method of controlling schistosomiasis but without provision of safe alternative water sources nearby for domestic purposes the distances involved become excessive. Early studies by Greany (1952) in the Sudan Gezira Project, suggested that distances in excess of 1km were required to reduce transmission even for young children. Such distances are impracticable at Mushandike.

Ideally, the criteria to be applied in the location of villages are that they should be as far as possible from the main canal and from the night storage reservoirs both of which are likely to support snail populations. In addition, a plentiful supply of safe water should be provided nearer to the houses than the nearest point of the irrigation system.

In practice, the location of most villages has been determined either by the location of existing boreholes or by the location of areas of cleared land which are not being used for irrigation. One issue which remains to be solved is the best manner for groundwater engineers and irrigation planners to collaborate in locating boreholes for village water supplies. It is unrealistic on the part of irrigation planners to expect groundwater engineers to locate a borehole at a precise point suitable for a particular village location - hydrogeological factors must be taken into consideration. Conversely, it is of little benefit for the purpose of careful village location if the groundwater engineers locate boreholes as much as 1km away from the original reference point even though this may be acceptable in providing water to an existing village in a drought- prone dryland area. Clearly, the two groups must work together in the field to find an acceptable compromise location.

4.4.2 Domestic water

No firm guidelines are available on an acceptable supply rate for domestic water to reduce water contact with potentially contaminated sources. In normal situations DERUDE (1983) recommends one borehole for 25 families whereas Jordan (1985) appears to recommend a maximum of 10 households for each communal supply point if schistosomiasis control is specifically intended. These figures depend on the yield of the boreholes and on the supply rate of the hand pumps which are fitted to them. In the fissured granite around Mushandike, borehole yields per capita are problematical. With regard to consumption, Jordan (1985) quotes per capita consumption rates to achieve schistosomiasis control of 50-60 l/day but this is for individual household supplies. It is unlikely that per capita consumption rates would exceed 25 l/day from communal supplies. An important part of the monitoring exercise at Mushandike will be to assess water consumption rates and to monitor borehole yields.

At present there are relatively few boreholes in existence at Mushandike and careful consideration should be given to increasing their number - a decision not to be taken lightly in view of the cost of drilling new boreholes. The question of water quality should also be kept under review. Groundwater is being used by preference at Mushandike because it is potentially of much higher quality than surface water but since a larger number of latrines are to be built in the region contamination might occur : the percolation of groundwater and contaminants in fissured granite is difficult to predict.

4.4.3 Laundry slabs

Location of well drained laundry slabs adjacent to water sources has been recommended. Monitoring the performance of these slabs and their acceptability to the villagers will be important.

4.4.4 Cattle

The watering of cattle at domestic water supply points or in the irrigation canals and reservoirs is to be strongly discouraged in order to prevent damage to structures and the creation of unhealthy swamps. If there are to be significant numbers of cattle in the vicinity, proper provision for their watering must be made.

The fencing of the irrigation system from cattle will be important although it is expensive and will require good maintenance. Hedges of suitable fast growing shrubs or cacti could be used.

4.4.5 Sanitation

Provision of individual family latrines in the villages has been agreed and participation in their construction will encourage their use and maintenance. Although the sub-soil is extremely rocky, pits in excess of 2m depth can be dug but supervision of construction may be required to ensure an adequate pit depth. The question of whether latrines should be provided in the fields is one we should discuss. Being communal latrines they may not be well maintained. Furthermore a high density would be required if they are to adequately serve all the field areas. It is possible that the relatively low level of contamination in the fields which would result if latrines were not provided could be tolerated but dangers will arise if defecation occurs in specific areas such as drains. Foci of transmission could then quickly develop.

4.4.6 Fishing and recreation

Both fishing and recreation have been identified at earlier stages of the project as activities which might be significant for the transmission of schistosomiasis. To date no special measures have been taken either to discourage these or to encourage the use of "safer" water bodies if any exist. The question could usefully be explored further.

4.5 Future developments

The measures described above are the ones which we believe offer the best possibility of controlling schistosomiasis with the constraints under which we are currently working at Mushandike. Other approaches may, however, be more effective either in later stages of the Mushandike project or elsewhere. Discussion of the practicability of some of these options would be worthwhile. An introductory list is given below.

(a) a more flexible operating policy for the main canal which would allow the size of the night storage reservoirs to be reduced;

(b) elimination of night storage dams by combining a degree of main canal storage with (a) above;

(c) elimination of secondary canals by use of pipes which could supply water direct to field canals;

(d) introduction of biological and/or chemical control methods to supplement the engineering control measures at selected locations; and

(e) use of a reticulated domestic water supply using the relatively clear and uncontaminated water of Mushandike Dam.

4.6 References

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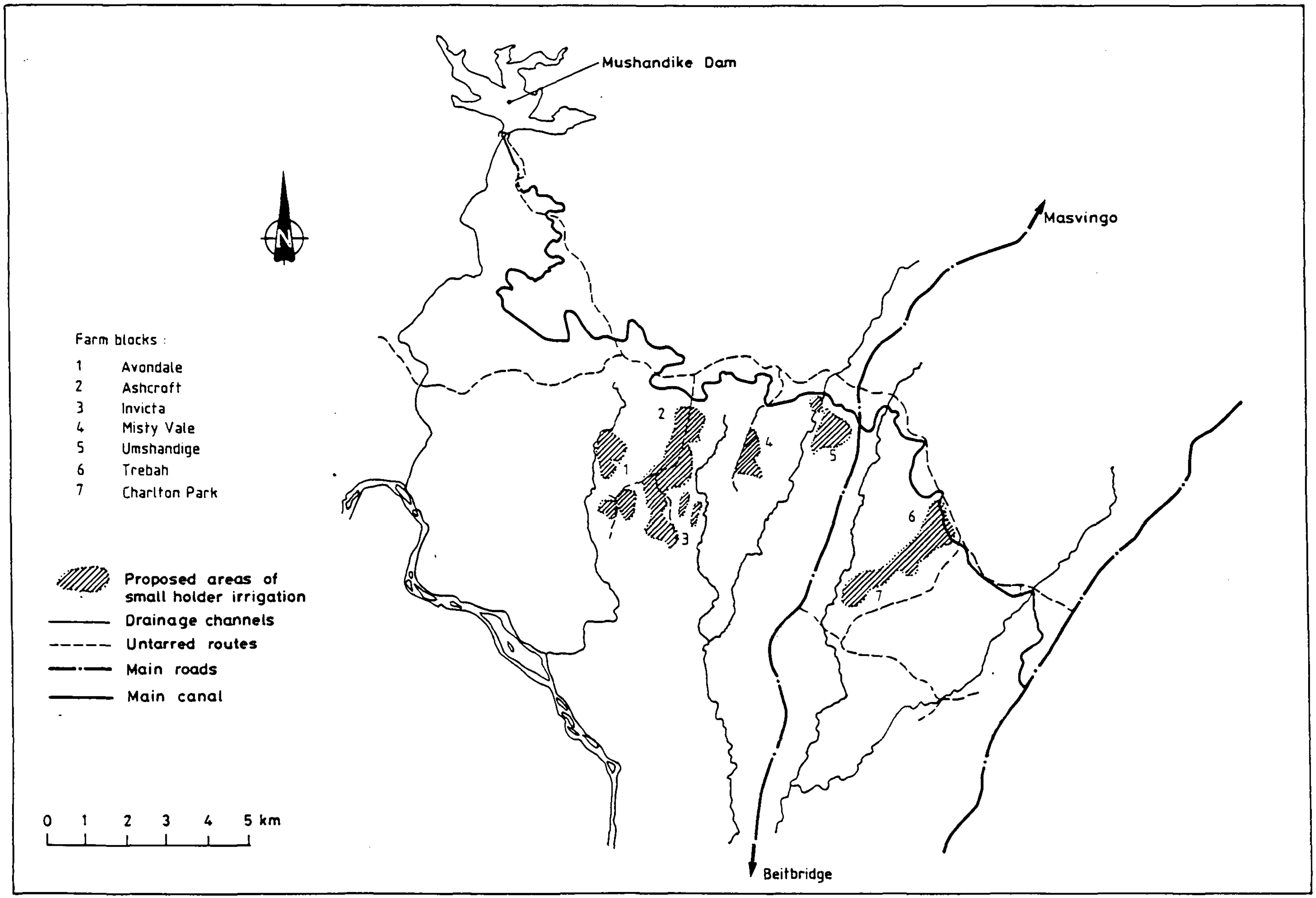

Fig 4·1 General plan of Mushandike Irrigation Scheme

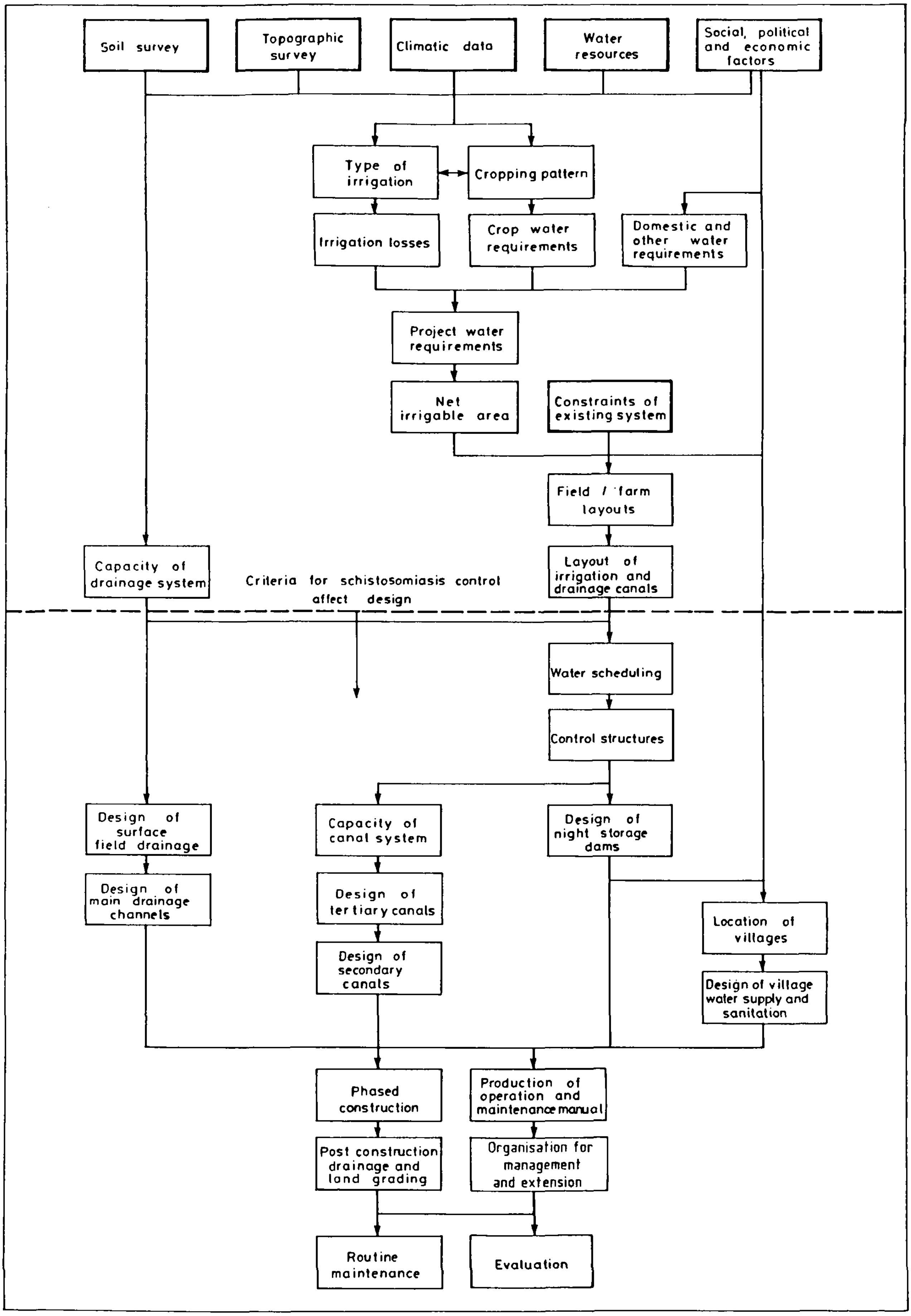

Fig 4·2 Flow diagram for the design and implementation of the Mushandike Irrigation Scheme

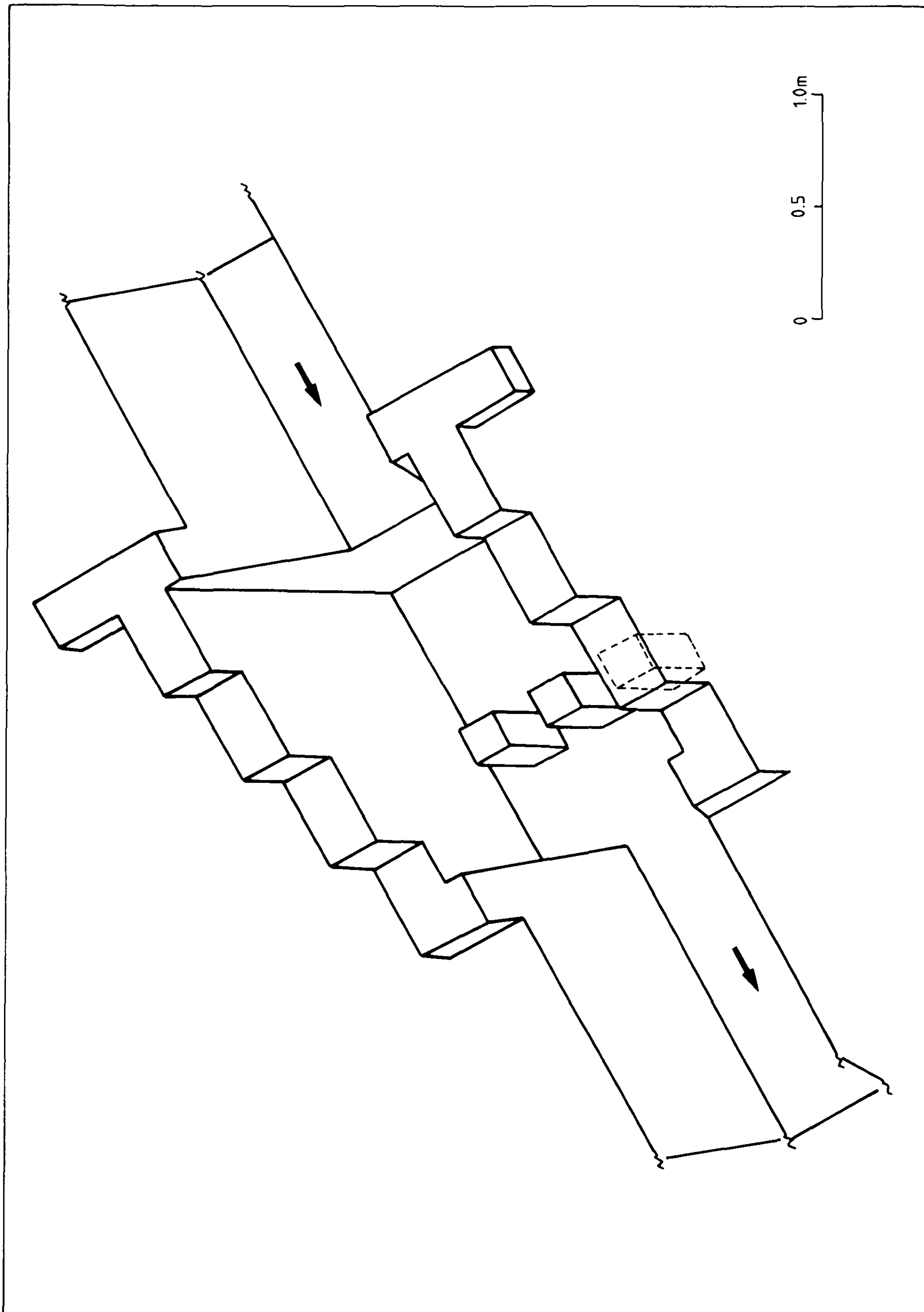

Fig 4.3 Free draining drop structure

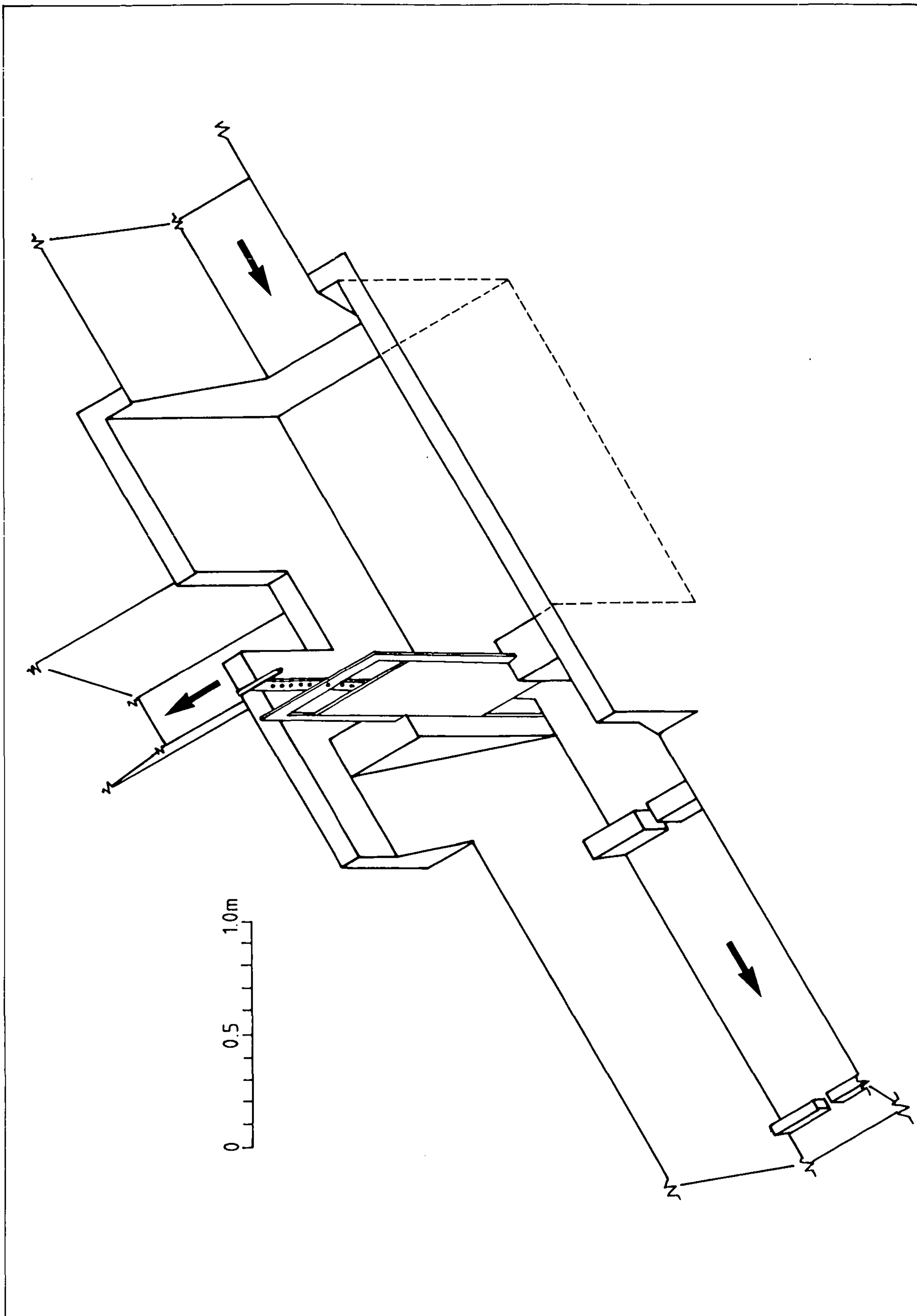

Fig 4.4 Possible design of off-take structure

5 EVALUATION OF APPROPRIATE TECHNOLOGY FOR WATER SUPPLY AND SANITATION

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5.1 Introduction

In Zimbabwe's rural Water and Sanitation Programme reliance has been placed on a relatively small range of technologies, and it is noteworthy that most of these have been developed in Zimbabwe itself. The success of the water and sanitation programme depends on many factors, but very high on the list is the appropriateness and effective functioning of the technologies in question. In the evaluation of the technologies themselves, perhaps the study of the functioning of the apparatus is of greatest importance. In this paper I shall refer most to information which has accumulated over the years from observations made by research and field staff of the Ministry of Health in their rural programmes. It is important to point out that other evaluative studies, which include those relating to sociological and anthropological subjects and their impact on the daily life of the rural population, have been undertaken, and have been reported on in the Water Master Plan, MEWRD (1985), and other related documents.

Those of us in the Ministry of Health have come to rely on a range of technologies which become more well known by Government specialists and the rural populations as the years pass by. It is surprising, however, that the great fund of knowledge which has accumulated over a period of years has never been documented fully, and many field workers often search for answers when technical questions are asked in the field. It is hoped that in time the combined experiences of field technicians, and the evaluations they have made in the field, will be documented and circulated fully to all field operators. To a certain extent, the Blair Research Bulletins attempt to perform this task, but far more information is at hand.

In a discussion of the evaluation of water and sanitation technologies used in Zimbabwe, we must discuss the following range of options being used at the present time by Ministry of Health field staff. They are:

- the Blair Latrine
- the protected spring
- the upgraded well
- the Bucket Pump in association with the Vonder Rig
- the Blair Pump
- the Bush Pump
- sand filters for family and small community use
- hand washing facilities.

Although other technologies are used, it is sufficient for the sake of this discussion to evaluate the functioning of the technologies listed above.

This technology is familiar to most of us here, and there is no need to describe exactly each in detail. What is important is to discuss the merits, failures and other factors which affect the functioning of each in field conditions. Clearly some technologies are more popular, and more successful than others. Some suit specific roles, others can be used in a broad spectrum of situations.

5.2 The Blair Latrine

This sanitation technology is well known in all the provinces of Zimbabwe, and has been accepted as the sanitation technology of choice for the Rural Areas in Zimbabwe. Each province has an active sanitation programme and, almost without exception, such programmes have been successful when implemented. The sanitation programmes are subsidised with donor aid moneys; the most successful implementation mechanism involves a subsidy being given for every family unit built. This is always in the form of bags of cement. This technique has been compared to other methods of aiding the programme, but has now been accepted as the most efficient and effective. The recipient (family) provides labour, most of the materials and the costs of hiring a builder, etc.

Early Blair Latrines were built following a very strict plan and the properties of the systems could be guaranteed. In more recent years many varients of the original design have been used, many of them arising in the Provinces. For instance, the designs used in Matabeleland and Manicaland are distinctive and quite different. It appears to have been established, for instance, that a single compartment model is acceptable in Matabeleland, and indeed several other provinces, but not the case in Manicaland where a double compartment version is recommended. The latrines being constructed at Mushandike follow a design similar to that shown in Figure 5.1.

Although it is estimated that well over 100 000 Blair Latrines have been built in the last 10 years, it is also clear that a certain proportion of these, possibly as high as 30% or more, are not built properly. Several evaluative studies reveal the inadequacy of home made ventilation pipes made from bricks as well as the lack of protective screens for the pipe. Other studies reveal inadequate pit lining in soil which may be soft, resulting in collapse of the structure. In the past there has been a tendency to dig pits which are too shallow, although this situation is improving, especially since there has been a national call for higher quality and permanent Blair Latrines. Low cost, short life models have been rejected by the Health Inspectorate and the public, and this trend reflects the interest placed in sanitation throughout the country. In addition studies show that structures may be too dark and unacceptable to many users. Grass roofs have been fitted to many structures in some areas of the country, but the evidence shows that these offer only a temporary solution. Very often the latrine floors are not hygienically shaped, which leads to inefficient washing down, and a generation of odours. All of these technical problems can be overcome by vigorous training exercises and the liberal distribution of high quality educational literature. Fortunately, a great deal more good educational material is now available, although it is not yet sufficiently distributed to be fully effective. A lack of knowledge and good instructional plans automatically leads to faulty construction. The vent pipe is a good example. Very often these are made so that the interior hollow is too small. If the pipe is not high enough, the whole system will not ventilate well and odours will be produced in the latrine. Thus there may be little or no advantage in constructing such a pipe. If the pipe does not lie over the pit, the properties of the system will also fail. Very often it is possible to identify a common fault in one area of implementation. If the instructor is teaching a poor design, it will be copied many times. An instance of this occurs at the Domboshawa training centre, where one model of the Blair Latrine has been built with the squat hole in a poor position. This "model" has been copied many times since, but each replica of the faulty original is itself faulty.

From the point of view of efficiency many studies show that mass produced PVC ventilation pipes are far more efficient than home made brick pipes since air moves freely up them without disturbance. However, the brick pipe is used almost everywhere since the materials are locally available, a factor of importance in rural development schemes. The lack of good fly screens has also resulted in many latrines nationwide not offering complete fly control. Such studies show that many pipes are fitted with either no screen or a poor quality metal screen which corrodes rapidly. It has even been reported that ½" chicken mesh has been used as a flyscreen in at least one area of Zimbabwe. Clearly this has little value. Fortunately some donor agencies have been generous in providing screen material. Large quantities of PVC coated fibreglass have been used for some years, but studies show that this has a maximum life of less than 5 years. Stainless steel screens which last for an indefinate period are now preferred and recently 20 000 pieces were donated by WATER AID UK. A further 20 000 pieces are on their way from UNICEF. Some provinces are building up to 6000 units a year and the national requirement actually exceeds this figure.

Stainless steel screen is distributed from Blair Laboratory.

The "smoke test" is used in most provinces to judge whether a Blair Latrine has been built correctly enough for the ventilation effect to work. If correctly built and sited, air should be drawn down the squat hole and pass up the pipe. If this does not happen there is a fault in the construction or the siting of the latrine. Latrines built near trees or higher buildings do not ventilate well. An experienced field worker can approach a latrine, go inside, and within a short space of time judge whether or not the construction is good. Often the nose is used, since the air inside the structure should be fresh.

Normally family latrines are maintained well and this should always be encouraged with plenty of washing water being used to flush down the floor slab. This simple procedure is important, as is the strength of the concrete in the floor. If this is too weak, as is often the case, the floor erodes and urine percolates into the floor and causes an odour which the vent pipe cannot remove. Multicompartment Blair Latrines are becoming more popular and slowly replacing the older non ventilated latrines and also single units which have often been put up at schools. Evaluations of the multicompartment structure show that they are more economical in terms of the use of bricks and often neater than rows of single units.

The pit structure of the Blair Latrine is designed to last for 10-15yrs but future evaluations may show that families may prefer permanent desludgeable systems, especially in the permanent growth points. Some evidence suggests that such units may be desirable, especially in peri-urban development areas, and possibly in growth points where the space available for repeated knocking down and rebuilding of latrines is limited. It is also possible that, in future years, there may be a need for Blair Latrines to be upgraded to more permanent water borne units.

A lot more may be said about the functioning of the Blair Latrine but I shall now pass on to the subject of water supply.

5.3 The protected spring

Most water supplies of this type have been built in Manicaland, although some potential exists in most other provinces to a greater or lesser extent. Years ago many were made in Midlands Province and the Mashonaland Provinces. An example is shown in Figure 5.2.

Clearly no technique is better than the use of gravity to provide water to a community: the technique has been used successfully by man for thousands of years. The great advantage of the system is its great reliability. Normally gravity systems function very well and over long periods of time without high inputs for maintenance. That this is so has been recorded in Manicaland, where over 500 units have been built many of them in the Honde Valley and elsewhere.

There is some discussion as to whether gravity schemes offer the best quality water but, to my knowledge, the bacteriological quality of spring water has not been tested fully in Zimbabwe, partly due to a lack of test kits and trained personnel. However the reliability of a source is as important as its quality and certainly springs have developed a reputation for reliability. The great success of the Malawi piped gravity water schemes has partly been offset by the evidence of faecal contamination in the water supply and of course the ideal is to provide a safe and reliable supply at one time.

I do not think gravity springs, gravity wells and syphon wells are used enough in Zimbabwe and many suitable sites have been missed, possibly through a lack of experience and training of new recruits into the rural health service. It is certainly an area which deserves far more attention.

5.4 Upgraded wells

More people in Zimbabwe take water from wells and water holes than any other single source of domestic water. It is estimated that currently there may be between 50 000 and 100 000 unprotected wells in use in Zimbabwe. Clearly this is a major source of water and far exceeds that delivered from rivers and boreholes. However monitoring programmes show repeatedly that the quality of unprotected water is poor and, during times of poor rains, unreliable.

Considering the importance of wells in our National Water Supply Programme, and the fact that much of the responsibility for upgrading wells lies in the hands of the Ministry of Health, I think that a lot more time, effort and funds could be channelled into upgrading these important sources of water in the communal lands. Very often wells are owned by the family and often such families cannot afford the expense of fitting a handpump. Evaluative studies show, however, that by improving an existing well by lining the walls, constructing a hygienic apron and water run-off channel and the use of the time tested rope and windlass, then the quality of the water extracted is significantly improved, the chance of parasitic worm infections being transmitted is reduced and the safety of the well itself for animals and children is enhanced. These are all important factors which deserve consideration and show that by simple means very traditional water resources have a significant role to play. An upgraded well is illustrated in Figure 5.3.

Studies carried out in the Water Master Plan reveal the relatively small percentage of wells which have been improved. In the communal lands approximately 7% of persons use water from improved wells compared to over 20% for boreholes. However between 30 and 40% of people living in rural areas rely on unprotected wells as a source of domestic water. These figures reveal the considerable importance of the traditional well and the urgent necessity for the Ministry of Health to step up its important contribution in the upgrading of such water supplies. Clearly there is a requirement for more funds and expertise in this critical area of improvement of facilities in the rural areas of the country.

5.5 The Bucket Pump

This is a relatively new technology introduced into our rural water supply programme and one that is currently being evaluated by Ministry of Health staff mainly in the Masvingo and Mashonaland East Provinces. It is not well known in Matabeleland, Manicaland or the Midlands as far as I know. It has certainly been treated with suspicion in some areas and, of course, the future of the system depends on its success or otherwise in development schemes in the rural areas.

The Bucket Pump was developed as a means of making village level maintenance of a pump a practical possibility in the village itself. We are all familiar with the fact that, in many if not most cases, the outcome of handpump breakdown means that the water supply may go out of action for some time whilst a trained technician is called and comes with suitable spares and tools. This is particularly true of the Bush Pump and also the Blair Pump. Spares are specialised and stocked normally by government departments. Clearly if a pump is installed in a remote village and breaks down the villagers have an immediate problem, how and when will the pump be repaired? Many evaluative studies show how poor handpump maintenance schemes are, both in Zimbabwe, and even more so in other developing countries. This is a real problem and one which faces all of us.

We have already mentioned the very large numbers of traditional wells in use in Zimbabwe and these continue to function without external funds or technical expertise. The reason for this is simple enough. The technology of the bucket, chain and windlass is understood and truly manageable at the village level. This cannot be said for any conventional handpump. The Bucket Pump is but one small step from the traditional system and thus offers the possibility of real village maintenance within reach, see Figure 5.4. The one feature of the Bucket Pump which does not already occur in traditional practice is the valve at the base of the bucket. This one piece is readily observed every time it comes out of the well and can be understood. There are many instances when the valve may have fallen apart or come loose in the rural installation but some how the pump has been re-established due to local ingenuity. I have samples of homemade valves and local innovations which have made the Bucket Pump work where more complex designs may have failed due to unmanageable breakdown.

As with most technologies there are some advantages and some disadvantages and these have revealed themselves in evaluations made of the pump in various rural areas. Of the disadvantages one can list the slow rate of delivery, between 5-10 litres per minute, the desirability of the chain and its theft, although this has not been a big problem. There are cases of chains being replaced by traditional rope, washing lines, electric wire and other cables. What concerns many health inspectors and health assistants is that it appears to be a very unhygienic apparatus compared to a handpump. This is possibly true enough since the tubewell is exposed and objects can fall in or be thrown in. The evidence so far to hand reveals that if this abuse does occur it is not common. This is probably due to the fact that Bucket Pumps are normally installed on tubewells which are hand drilled by the community.

Bacteriological records show a remarkably low level of E.coli in the water from Bucket Pumps. This rather surprising result is consistent and not what one would expect from a well used with a windlass and chain. However there is a good reason why water quality should be enhanced in the Bucket Pump. When one considers that fresh water is entering the base of the tube and being extracted by the bucket, it is easy to visualise the high rate of change of water in the tube. Any potential contaminants are diluted rapidly by fresh water entering from the bottom of the tube. The result is an improved quality water.

The overall evaluation of the Bucket Pump is now being undertaken in Masvingo where approximately 500 units are now in operation. It may require several years to judge where this system has merit, for its slow rate of water yield may outway its advantage of local possibilities for maintenance. It is more likely, however, that the good chance of local maintenance will mean that it will continue to operate where other pumps would fail. In the end it is not the efficiency but the reliability of a system which is most important.

5.6 The Vondor Rig

This hand operated drilling rig first came into operation in 1983 and was first used in Epworth, near Harare. Since that time over 350 tubewells have been sunk in Epworth solely with the rig and in this area it has been a major success.

Over 100 rigs of this type are being used in various water development schemes in Zimbabwe and many of these are enjoying considerable success. However this is not the situation everywhere. Clearly the rig is not designed for drilling through rock and it cannot penetrate gravel or pebble layers in the ground. This limits its success in many areas. What has become apparent is the importance of performing trials with the rig in certain areas before major schemes are planned. Many areas of Mashonaland and Masvingo have seen the rig used with considerable success and this makes possible very effective community participation. In Matabeleland and Manicaland it has enjoyed less success. It is hoped that many areas of the Midlands province may find it useful.

The Vondor Rig makes possible the excavation of a narrow diameter tubewell which penetrates the ground down to bedrock. This means that drilling can be performed at any time of the year and that the ground water can be penetrated completely above the base rock layer. In suitable areas drilling can be finished in less than two days even with holes in excess of 12-15m. It has been noted that the rate of wear on the drilling bits can be high and a system of sharpening and repair of the cutters is very essential to support the drilling programme. A supply of steel rope and pulley wheels is also desirable but none so desirable as the oil can and its regular use.

Several problems have been encountered not only at the drilling stage (usually as a result of hard or difficult soils) but also with regard to the yields of water derived from the tubewells. Whilst it is acknowledged that low yields may often be due to the poor permeability of the soils, and their reluctance to release liberal quantities of water, this is not always the case. Very often the use of a poor gravel pack surrounding the PVC casing has resulted in complete blockage of water flow from the aquifer into the casing. Since many tubewells are drilled in more remote places, it is not uncommon for the gravel pack to be chosen from local sites. Such packs are often made from local sands which have a high content of fine material; even river sand, when unwashed, can be unsuitable. The result is a clogged gravel pack, where the rate of infiltration into the casing is so slow that the pump dries out the well very quickly. It is very desirable in areas where suitable gravel pack material is not available to import suitable material on a lorry to the site. The quantity of such material is not great but well worth the effort.

It is hoped that this valuable technique will be used more and more where soils permit.

5.7 The Blair Pump

During the first 4 years, 1976 to 1980, the early models of the Blair Pump developed a good reputation for their strength and reliability. Each was hand built. In the early years of mass produced Blair Pumps, its reputation failed badly however, due to regular breakdowns. The Blair Pump has been designed for its simplicity of installation and maintenance, see Figure 5.6. There remains no doubt that it is still the simplest handpump to install and maintain compared to others. Approximately 8000 units have been made by the manufacturers since 1980, but it is unlikely that more than 2000 of these had been in regular service until significant improvements were made to the pump in 1984/85.

The early problems of the Blair Pump were not uncommon to most pumps installed by technicians who also had many other responsibilities. Pump breakdown was partly due to poor pump quality but also to poor pump installation. As with all aspects of the rural water supply and sanitation programmes, a lack of thorough training in how to build and install rural health technologies was one of the main reasons for the failure of this and many other systems. Many studies made of pump breakdown show defects in the headblock assembly of early pumps. Poor cementing techniques for the PVC pipes also resulted in separation of the pipes during plumbing. Badly mixed and cured concrete head blocks resulted in many pumps falling into wells. The critical PVC to steel joint had not been perfected in earlier models. In addition, valves in earlier pumps were made of soft rubber and often failed.

Moreover the Blair Pump, being the cheapest to buy of all the handpumps, was placed in situations, often under heavy duty, which the pump was not designed to handle.

It is gratifying to be able to report that this dark era for the Blair Pump has passed. New models benefit from much improved headblocks, valves and PVC/steel joints, stronger sockets, PVC cement available in tubes, far better instructional literature, and the knowledge that the pump is intended for use by a few families and not entire communities. When installed correctly in the right setting and where an organised system of maintenance can be guaranteed, then the Blair Pump can be expected to provide good service. It still remains the easiest pump to install, apart from the Bucket Pump. Blair technicians can install 15 pumps a day in an area. A maintenance kit is available and it can be managed by Ministry of Health staff. It remains to be seen how successful this pump will be in future programmes.

5.8 The Bush Pump

This is the most successful pump used in Zimbabwe and is commonly fitted to boreholes and deep wells including those of the Mushandike Resettlement Project. It is normally serviced by the District Development Fund. Over 10 000 pumps have been installed since it was first introduced over 50 years ago. Like all other handpumps, the Bush Pump has its fair share of problems but these are not ones that are normally solved by Ministry of Health staff. More recently a modified Bush Pump has been designed for easier maintenance since all the working parts down the rising main, like the seals, piston and foot valve, can be removed through the rising main, see Figure 5.7. Various other aspects of the headworks have been improved. This pump is currently being evaluated for its durability and popularity. Being a steel pump it is far more durable than PVC pumps although the cost is far higher. The pump is now being installed in a few localities by Ministry of Health staff and it is hoped that in the future the Ministry of Health will pay far more attention to this robust and forgiving pump.

5.9 Sand filters

Although sand filters are known to work well they have not been used frequently, especially in family settings. The evaluations of this technique have not been extensive but it is clear that in most areas they have not been popular, possibly because, although they are relatively simple to build, they do require maintenance and care to run them successfully. This is an area which needs more attention in the future.

5.10 Hand washing

One of the most innovative and promising appropriate technologies in future programmes, apart of course from the common tap (which requires a piped water supply), is the "Mukombe". This simple hand washing device originated in Chiweshe. The design has been circulated amongst Ministry of Health staff, see Figure 5.8, but it is still relatively unfamiliar to most rural communities. This is partly because Mukombe's of the right shape are difficult to come by in the field. However, it is very clear that before many of the diarrhoeal diseases can be overcome in rural areas an effective means of hand washing is essential. Evaluations of the Mukombe have been made in only a few areas but these show positive signs and indicate that the system might become nationally popular. Certainly, where there is no tap, and this is the situation for most rural areas, the Mukombe may one day be regarded as a very big stepping stone to help hand washing and personal hygiene in the rural areas.

5.11 Conclusions

This brief report has attempted to summarise the advantages, disadvantages and problems associated with the appropriate technologies that are used in our rural water supply and sanitation programmes. It thus represents a brief technical evaluation of the functioning of the designs in use. Clearly a complete evaluation of these technologies would cover many other areas such as their use, acceptability and success in having a health impact. The present paper has not attempted to cover these aspects. It is hoped however that the report will be of value to those attending the seminar.

5.12 Reference

Ministry of Energy and Water Resources and Development (1985). National Master Plan for Rural Water Supply and Sanitation. Zimbabwe.

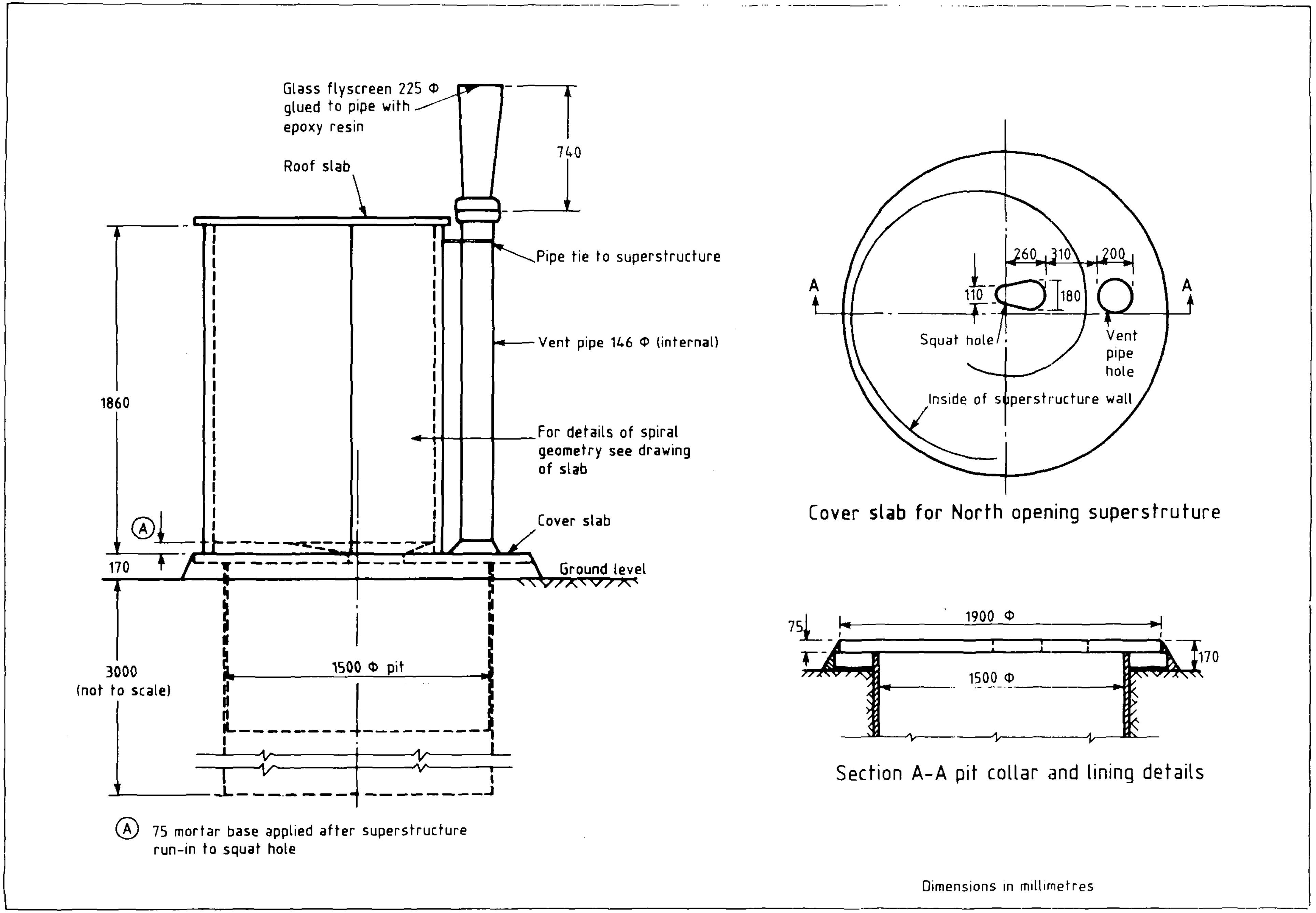


Fig 5.1 Ferro cement Blair Latrine

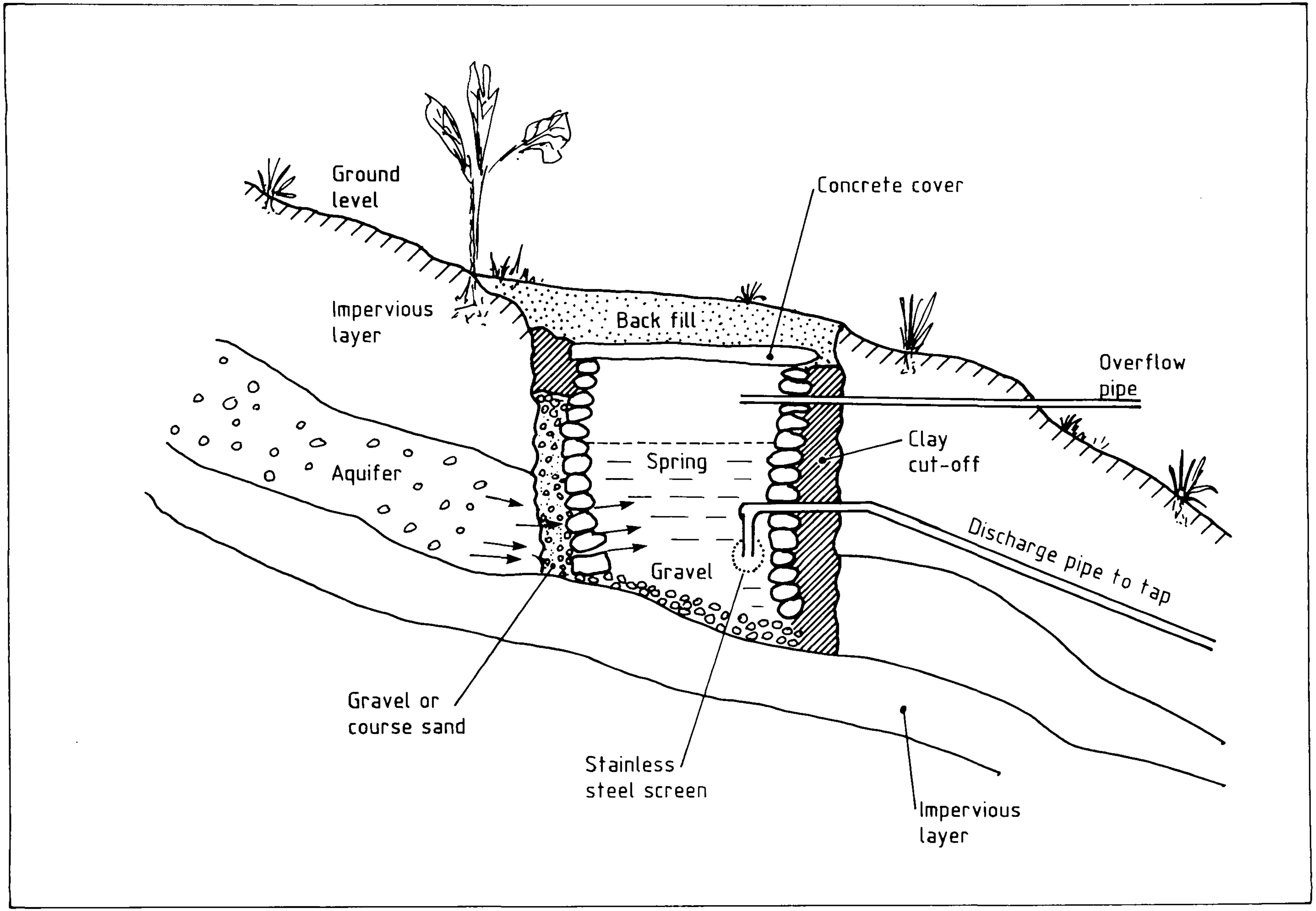


Fig 5.2 Protected spring with infiltration from back wall

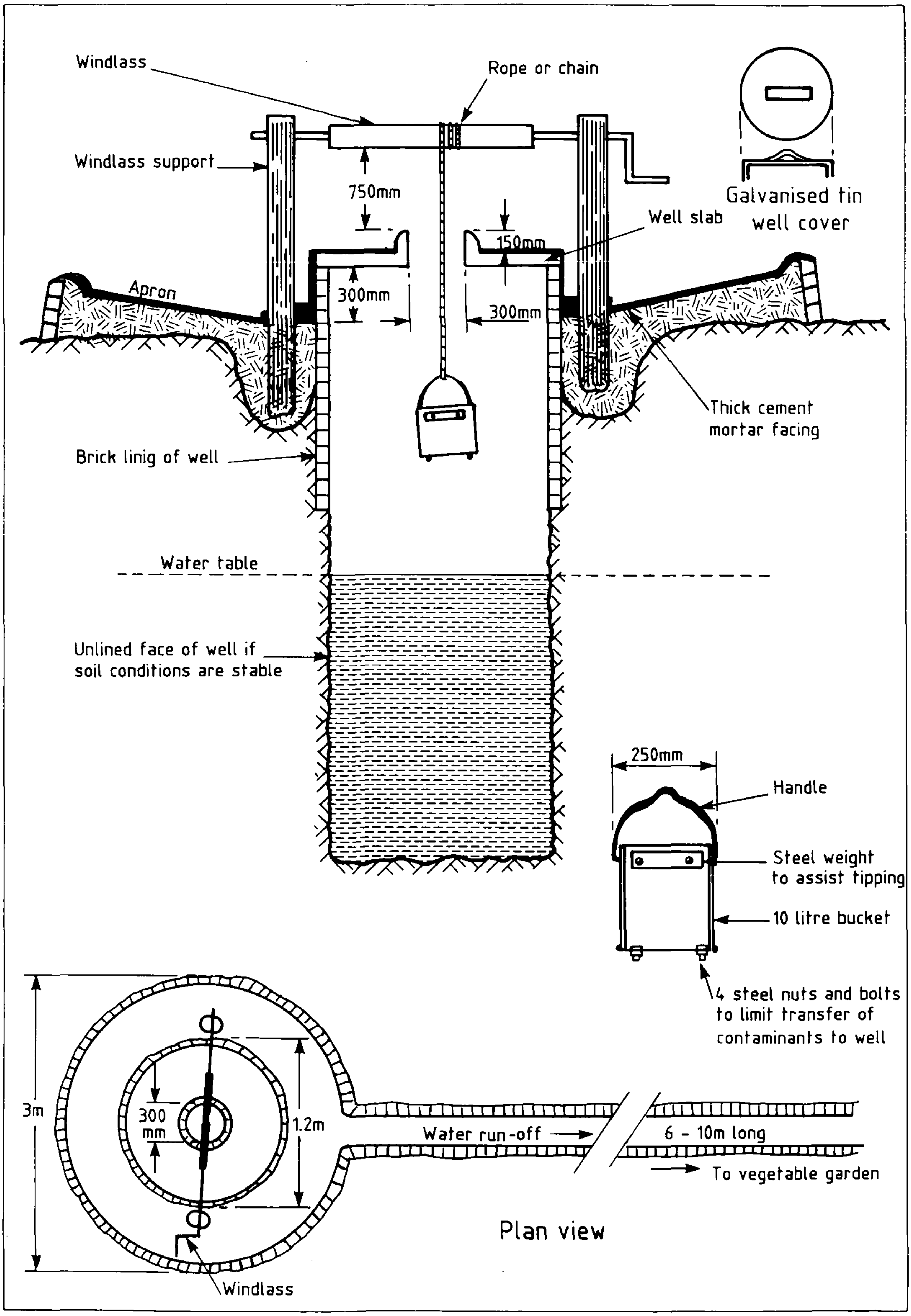


Fig 5.3 Upgraded traditional well

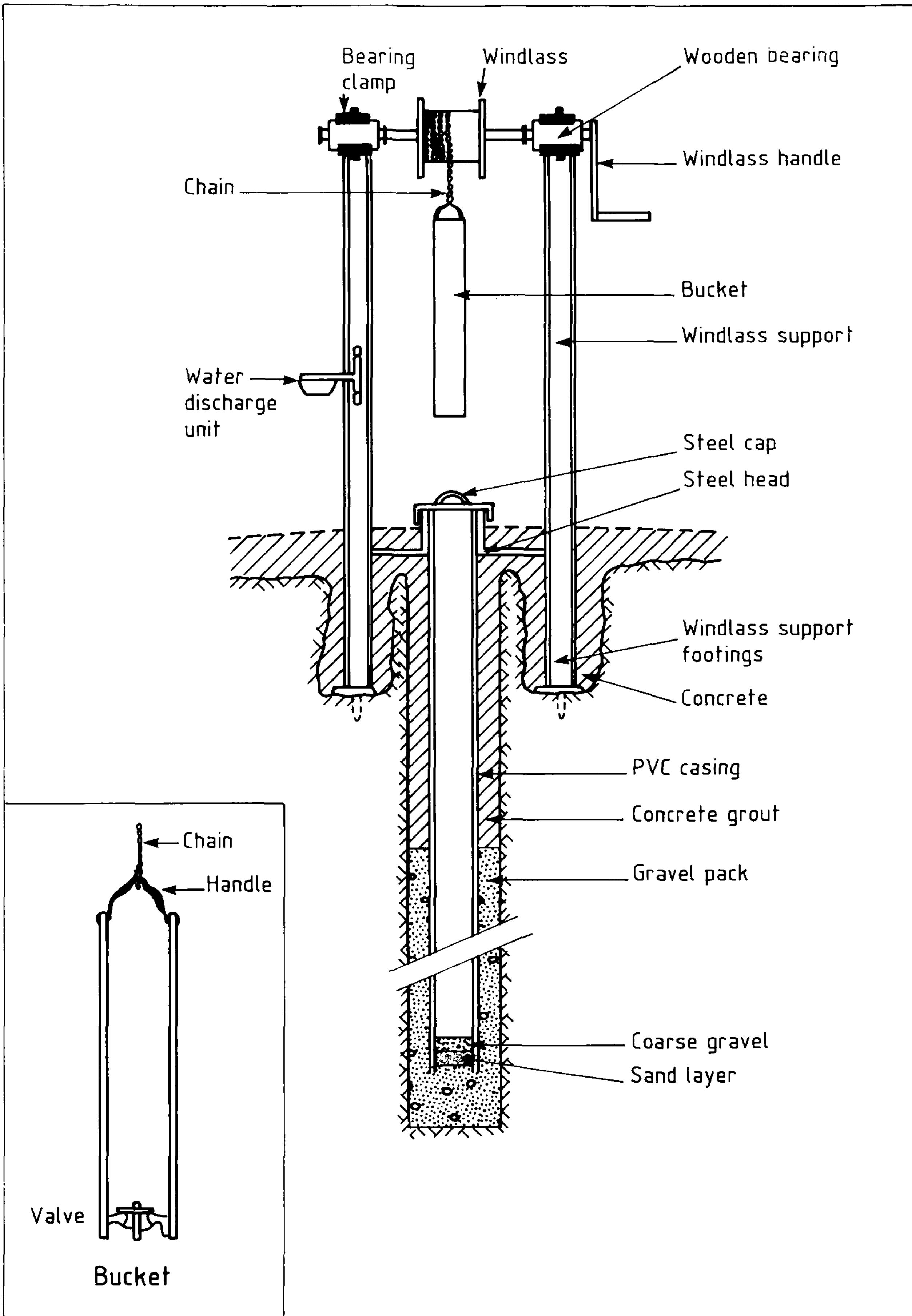


Fig 5.4 Bucket Pump

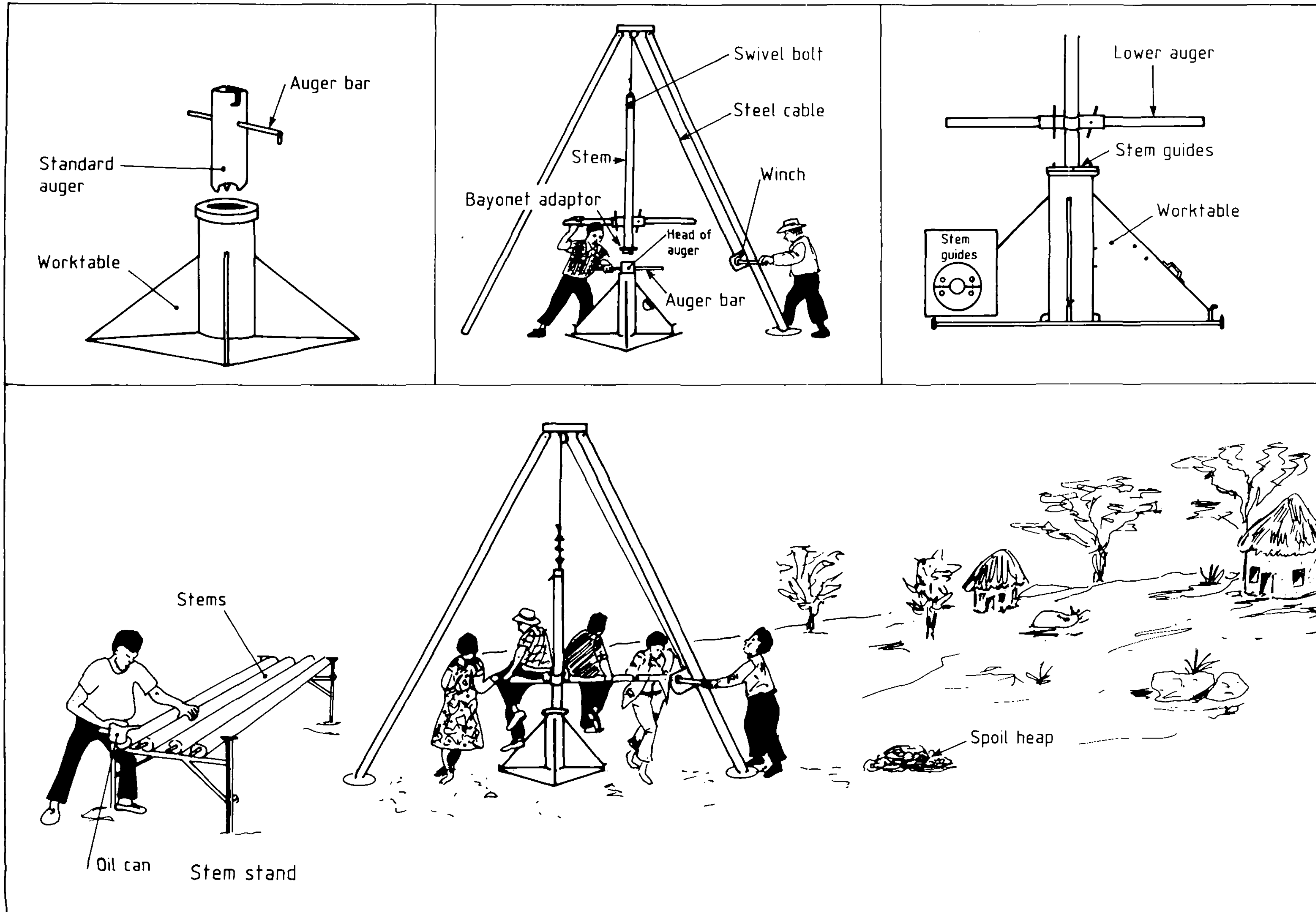


Fig 5.5 The Vonder Rig

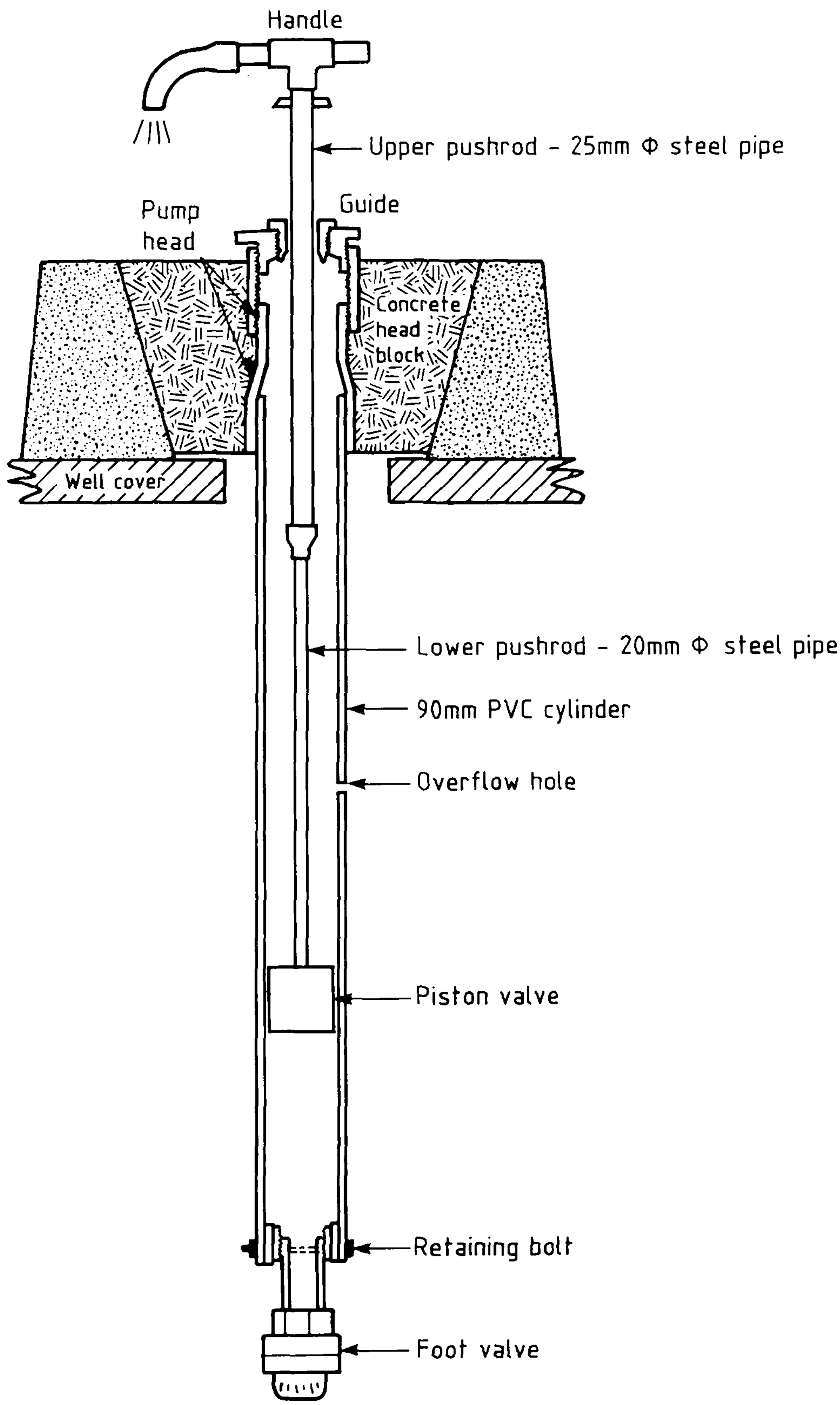


Fig 5.6 Blair Pump Mark 1c inserted in well

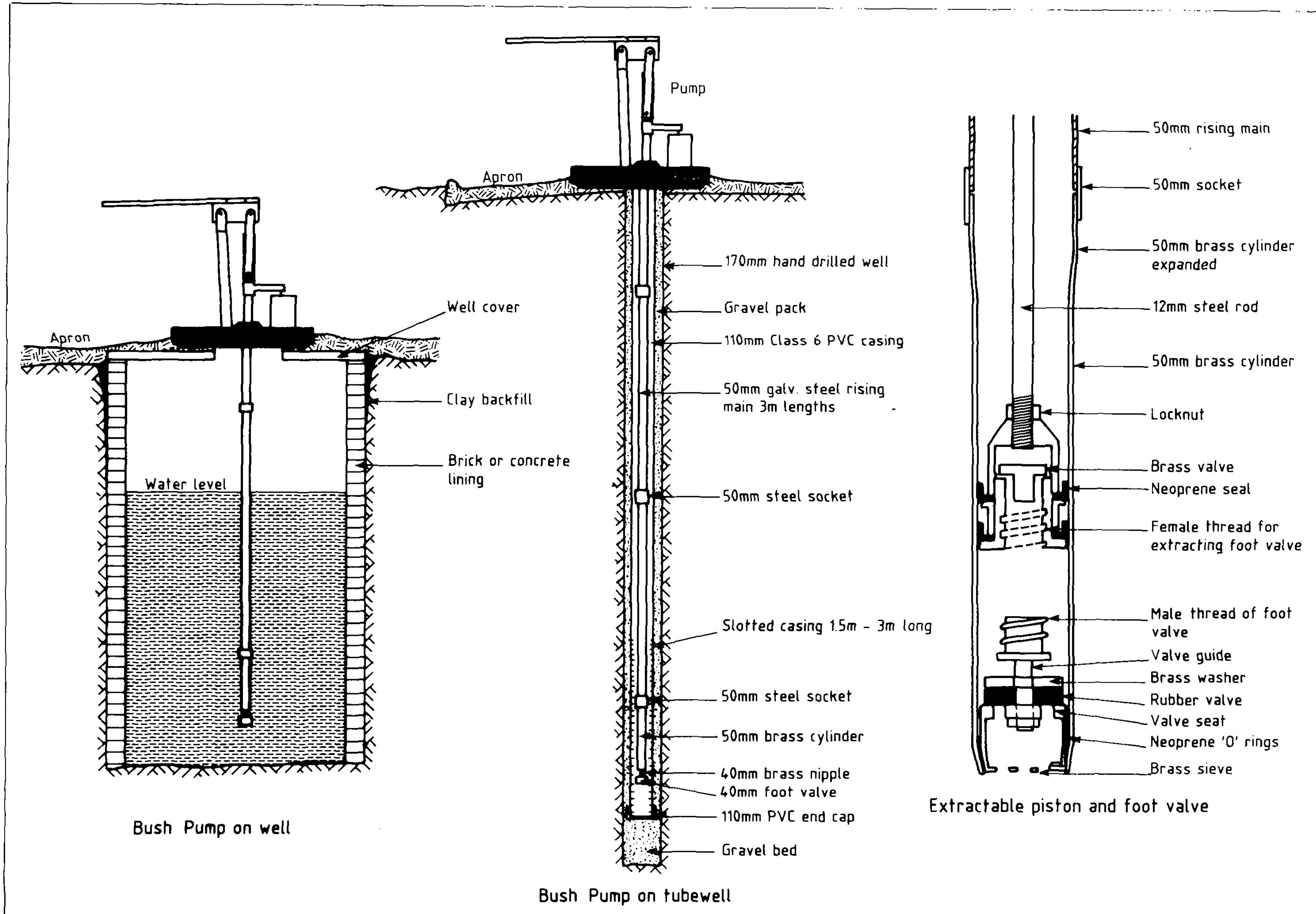
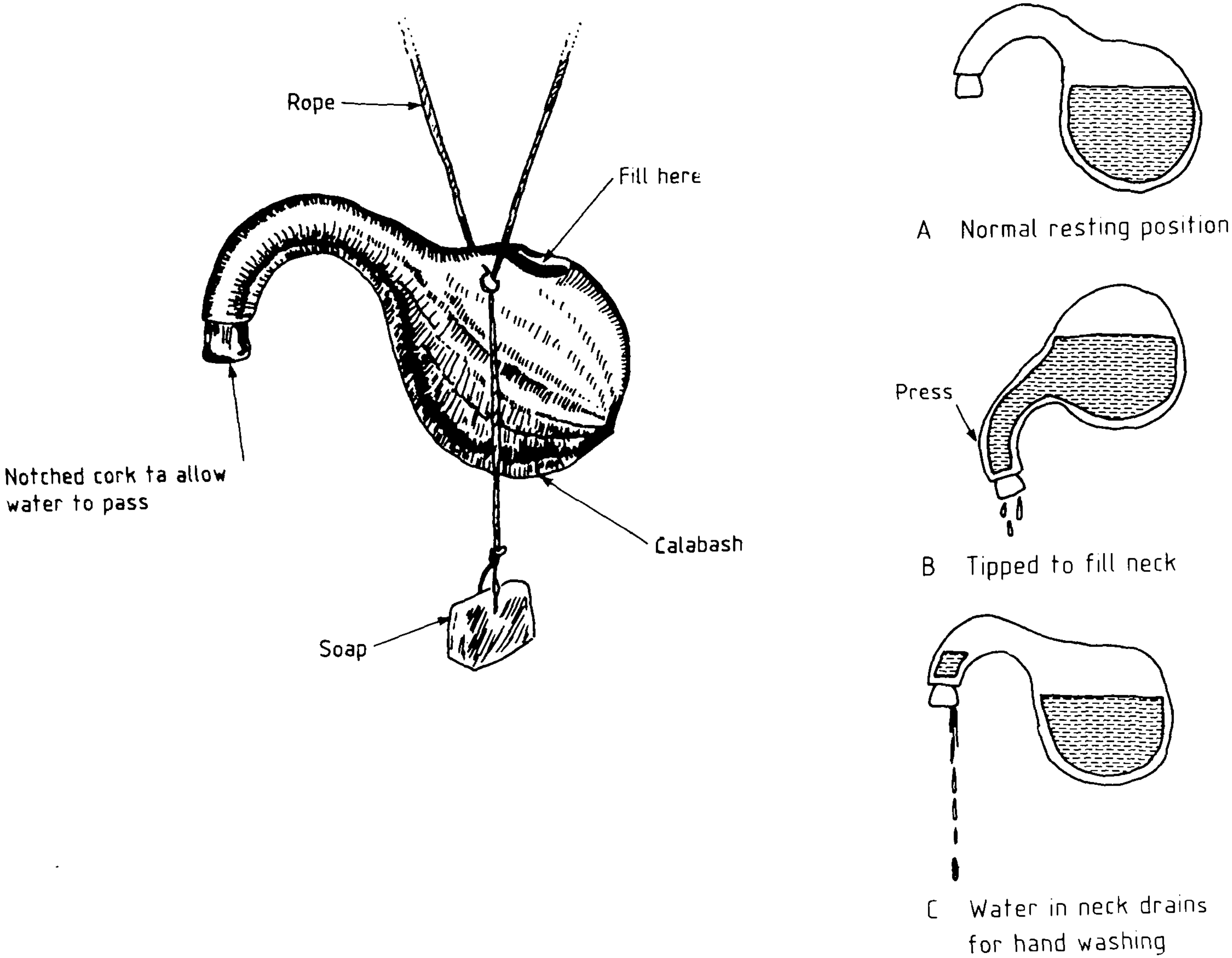


Fig 5.7 The V & W Bush Pump

Fig 5.8 The Mukombe



6 SCHISTOSOMIASIS CONTROL IN MUSHANDIKE IRRIGATION SCHEME: MONITORING, HEALTH EDUCATION AND EVALUATION

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6 SUMMARY

This paper concerns the monitoring, health effects and evaluation of schistosomiasis control measures in Mushandike Irrigation Scheme, near Masvingo town, in south-east Zimbabwe. The irrigation scheme was designed in accordance to environmental and engineering criteria which were drawn up in advance by Bolton and Draper (1985) in consultation with collaborating organisations in Zimbabwe.

Data are presented in the paper on the current programme to monitor schistosomiasis transmission in the scheme. There is a need to examine fully the issues raised in the paper by the various organisations attending the seminar for the effective implementation of the measures adopted against schistosomiasis.

6.1 Introduction

Irrigation schemes are often associated with increased health hazards through creating ideal conditions for the transmission of water-related diseases such as schistosomiasis, the second most important parasitic infection after malaria in Zimbabwe. In a review of the major water-related and vector-borne diseases in Zimbabwe, Chandiwana (1984) noted that the increased transmission of schistosomiasis in irrigation schemes was mainly due to the stabilisation of water courses making them ideal breeding habitats for the snail intermediate hosts and also causing increased human water contact. The author made recommendations for schistosomiasis control which included snail control with molluscicides and mass treatment of the human population.

However, these measures are unsustainable because of high recurrent costs. In order to reduce these costs, there is a need to incorporate, at the planning stage of an irrigation scheme, environmental and engineering designs for schistosomiasis control. Zimbabwe intends to boost agricultural production through the development of numerous small-scale irrigation schemes and it was decided to undertake a collaborative research project (involving Blair Research Laboratory of the Ministry of Health, the Ministry of Lands, Agriculture and Rural Resettlement and the Overseas Development Unit of Hydraulics Research, UK) into the effectiveness of environmental and engineering schistosomiasis control measures (see Bolton & Draper, 1985).

The measures include snail control through canal lining, design of structures and operational aspects (sluicing, flushing, and regular drying-out of canals and water level fluctuations in the reservoirs). Human water contact with reservoirs and canals will be reduced through proper siting of villages and the provision of water supplies and latrines at convenient and strategic locations in the scheme. In addition, the farmers and their families will be encouraged to use these facilities through health education.

I will now proceed to elaborate on the above aspects particularly monitoring, health education and evaluation for schistosomiasis control in the Mushandike Irrigation Scheme.

6.2 Monitoring schistosomiasis in the Mushandike Scheme

6.2.1 Background

The objective of this exercise is to monitor schistosomiasis transmission in an irrigation scheme designed to pre-empt or reduce transmission.

To obtain background information on schistosomiasis prevalence in the area, there being no people in the proposed Mushandike scheme in October 1984, it was decided to carry out parasitology and malacology surveys in Wallace and Gundry irrigated farms (Chikore area) which are located at the lower end of the Mushandike project area. Both Bulinus globosus and Biomphalaria pfeifferi, snail intermediate hosts for urinary and intestinal schistosomiasis respectively, were found in reservoirs and canals. Table 6.1 shows the results of a parasitology survey of 183 people at the two farms. It is clear from the table that schistosomiasis in areas immediately surrounding Mushandike Irrigation Scheme is markedly high.

6.2.2 Community discussion

Table 6.2 shows the programme of activities from October 1985 to September 1986. Since construction work in the scheme and resettlement are being carried out by the Department of Rural Development (DERUDE), engineering designs by the Department of Agricultural, Technical and Extension Services (AGRITEX) and monitoring of schistosomiasis prevalence by the Blair Research Laboratory (BRL), meetings and contacts among officials of the three departments are necessary and are an ongoing exercise. Officials of DERUDE and AGRITEX based in Masvingo (about 25km from the Mushandike scheme) are essential for the efficient monitoring of the control project. There is need for BRL to work in close liaison with the two departments not only for logistical support for the project but to ensure that other aspects of the project not under its control are in line with the criteria set to control schistosomiasis in the scheme (see Bolton & Draper, 1985).

Furthermore, contacts are necessary and have been made with other groups in and around the scheme, namely, the army camp, the Ministry of Energy and Water Resources and Development (MEWRD) and Village 8, a dryland resettlement village near the main canal just below the dam wall. Settlers arrived on Misty Vale block in May 1986 and discussions have been held with this group to acquaint them with the research team and explain to them the purpose of the control project.

6.2.3 Schistosomiasis surveys

In April 1986, a schistosomiasis survey was carried out among three groups of permanent residents in and around the scheme; the results are shown in Table 6.3. The three groups of residents are located in areas upstream of the project area and there is physical evidence that they use the section of the main canal passing through their area making them of importance as regards schistosomiasis control in the irrigation blocks under study further downstream. All infected persons in the three settlements were treated with praziquantel and the schistosomiasis situation in these areas needs monitoring.

A total of 85 settlers at Misty Vale farm were surveyed for schistosomiasis in July 1986 and the results are shown in Table 6.4. It is seen from the table that prevalence (11.8%) and intensity of *Schistosoma haematobium* (urinary schistosomiasis) is the same as that found in Village 8 (Table 6.3) and that cases of *Schistosoma mansoni* (intestinal schistosomiasis) are scanty for both settlements. Further investigations have suggested that people in the two groups of settlers originate from Chivi, a nearby communal area. It is likely that the infections found at Misty Vale are imported since the settlers had been on the farm for about a month only when the survey was carried out. At present there are no schools in the resettlement area and therefore many children of school going age were not available for examination. These children are expected on the scheme during the August/September school holiday when they will be examined and those found infected treated.

6.2.4 Snail and cercariometric surveys

In addition to monitoring transmission through measurements of the prevalence and incidence of schistosomiasis in the human population, transmission is being monitored through monthly measurements of populations of snail intermediate hosts and their infection rates and cercarial densities in the water. The whole length of main canal from the dam wall to Gundry and Wallace farms in the lower end of the Mushandike scheme was surveyed for snails during April 1986 and in July 1986. In addition, in July 1986, snail surveys were carried out in the night storage reservoir, secondary and tertiary canals on Misty Vale farm.

The results of the two surveys are shown in Table 6.5. Both snail intermediate hosts of schistosomiasis, B.pfeifferi and B.globosus, are present in the study area as well as Lymnaea sp, Melanoides sp and Bulinus tropicus. The last mentioned snails do not transmit schistosomiasis but were found in high densities in the canals and dams. For instance, in the night storage dam at Misty Vale many hundreds of B.tropicus were found whilst seven B.globosus and no B.pfeifferi were recovered. The ecological factors affecting the relative distribution of the different snail species need elucidation and may be important in understanding transmission dynamics of schistosomiasis in the area.

High densities of B.tropicus were also found in the secondary and tertiary canals in Misty Vale. These averaged 10 snails per 3m section of secondary canal and 2.4 snails for a similar stretch of tertiary canal. This distribution of snails throughout Misty Vale scheme has ominous implications for the health of the settlers if B.globosus and B.pfeifferi were to become established in the night storage dam.

It is imperative that the physical structures and operation of the scheme is in accordance with criteria drawn for schistosomiasis control (Bolton & Draper, 1985). Secondary canals are supposed to be dry for certain periods but this has been difficult to achieve because some water trickles into the canals from the off-take gates. Further, the sump areas could become marshy and water-logged creating ideal breeding habitats for snails.

Exposure of sentinel caged hamsters at various sites in the scheme will give us an indication of cercarial densities at each site. The species of schistosomes can also be determined. In addition, the technique has the potential not only for monitoring transmission but also for elucidating various aspects of transmission dynamics such as how far from a contact site rodents can still be infected at the centre of a canal compared to the edge of the same canal. Further elucidation of transmission patterns can be achieved by studies of snail population dynamics (absolute abundance, births, deaths and dispersal rates) and the associated infection rates. In April 1986, during the warm post rainy period, a proportion of B.globosus caught (but no B.pfeifferi) were shedding schistosome cercariae but in the cool dry month of July 1986 no snail intermediate hosts shed any cercariae. Other studies in Zimbabwe and elsewhere have attributed this phenomenon to sporocyst dormancy in the snails during the cool dry months of the year (Shiff et al, 1975; Pfluger, 1976; Chandiwana et al, in press).

6.3 Health education

The human population resident in the scheme should be educated through talks, plays, schistosomiasis pamphlets, posters and films on schistosomiasis. This should be done so as to increase the awareness of the disease among the population and thus ensure compliance with the control programme. Such awareness should also result in decreased human water contacts and deceased pollution of the canals and dams on the scheme as the farmers and their families use latrines and protected water sources.

Progress in building Blair latrines at accessible points in the fields is satisfactory but the absence of latrines in the resettlement village itself is a cause for concern. A borehole for the settlers of Misty Vale appears to be producing enough water for domestic purposes but the author laments the absence of a concrete apron and a drainage system to prevent the development of muddy conditions which are now evident. It is hoped that this situation will be remedied. Recently the Provincial Medical Director of Masvingo has assigned a health assistant to the Mushandike scheme and plans to provide cement to help the settlers to construct their own latrines. This is a step in the right direction.

6.4 Evaluation

The efficacy of the schistosomiasis control programme can be assessed by regular systematic sampling of a number of sites for snails and their infection rates. The effectiveness of the control programme can also be shown by the absence of infection or a low intensity of infection among high risk groups (teenaged children, workers whose occupation makes contact with water necessary, eg water bailiffs in the scheme). Such information will be obtained best by longitudinal incidence studies. If population movements in and out of the scheme are limited, valuable information can be obtained by comparing pre-control and post-control schistosomiasis prevalence and the intensity of infection.

Another way of evaluating the control programme is to compare pre-control and post-control prevalence and intensity in the controlled area with an adjacent area where no intervention takes place. The two irrigated farms of Gundry and Wallace (Chikore) to the south of the study area will serve as controls for the project. There is also potential for comparing the efficacy of the control programme between the various blocks (Misty Vale, Ashcroft, Invicta and Avondale).

However, there is concern that due to the phased implementation of the different blocks, the epidemiological results of the monitoring study may become confused by interaction of each new area of the project, as it enters operation, with areas already in operation. For example, whilst Misty Vale block is completed and already settled and at Ashcroft block work in the fields although not complete has reached an advanced stage and settlers are expected in October 1986, work on the other blocks has hardly begun. In the case of the Avondale block, development may not start for at least two years after irrigation begins on Ashcroft block.

In view of this possible interaction, it has been decided to intensify the monitoring programme from a quarterly to a monthly basis and to increase the monitoring to include snail surveys and cercariometry at selected sites as already described (see 6.2.4). In this way, the development of snail populations and transmission sites can be monitored in detail and so provide a basis for comparing the effectiveness of control measures in different blocks of the scheme.

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Table 6.1: Prevalence and intensity of schistosomiasis in Chilore area, October 1984

Farm	*Schistosoma haematobium* Prevalence	*Schistosoma haematobium* Intensity			*Schistosoma mansoni* Prevalence	*Schistosoma mansoni* Intensity		
	No infect (% of total)	Eggs/10ml infect urine (% of those infected)			No infect (% of total)	Eggs/g infect faeces (% of those infected)		
		< 200	200-500	> 500		< 200	200-500	> 500
Wallace	97 (53.0)	64 (66.0)	22)22.7)	11 (11.3)	26 (26.8)	25 (96.2)	1 (3.8)	0 (0)
Gundry	28 (46.7)	24 (85.7)	3 (10.7)	1 (3.6)	18 (30.0)	18 (100.0)	0	0

Table 6.2: Programme of activities from October 1985 to September 1986

ACTIVITY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Sep
Community liaison	*			*	*	*	*	*	*		
Parasitology survey							*			*	*
Snail & cercariometric surveys							*	*	*	*	*
Sanitation								*	*	*	*
Water supplies								*	*	*	*
Resettlement								*			
Mapping	*										

Table 6.3: Prevalence and intensity of schistosomiasis in three settlements in and around the project area

		Schistosoma haematobium				Schistosoma mansoni			
		Prevalence	Intensity			Prevalence	Intensity		
	*No Exam	No infect (% of total)	Eggs/10ml infect urine (% of those infected) < 200	200-500	> 500	No infect (% of total)	Eggs/g infect faeces (% of those infected) < 200	200-500	> 500
Army farm and camp	38	0 (0)	0 (0)	0 (0)	0 (0)	5 (13.2)	5 (100)	0 (0)	0 (0)
MEWRD	37	8 (21.6)	8 (100)	0 (0)	0 (0)	11 (29.7)	9 (81.8)	2 (18.2)	0 (0)
Village 8	17	2 (11.8)	2 (100)	0 (0)	0 (0)	2 (11.8)	2 (100)	0 (0)	0 (0)

* represents over 90% of the population

Table 6.4: Prevalence and intensity of schistosomiasis in Misty Vale block, July 1986

Schistosoma haematobium				*Schistosoma mansoni*			
Prevalence	Intensity			Prevalence	Intensity		
No infect (% of total)	Eggs/10ml infect urine (% of those infected)			No infect (% of total)	Eggs/g infect faeces (% of those infected)		
	< 200	200-500	> 500		< 200	200-500	> 500
10 (11.8)	10 (100)	0 (0)	0 (0)	3 (3.5)	3 (100)	0 (0)	0 (0)

Table 6.5: Snail intermediate hosts collected and their infection rates in 18 sites in Mushandike scheme

		B.globosus	B.pfeifferi
April 1986	No. caught	578	24
	No. shedding	26	0
	% shedding	4.5	0
July 1986	No. caught	15	11
	No. shedding	0	0
	% shedding	0	0

Appendix

7 AN EVALUATION OF MARK-RECAPTURE METHODS FOR THE STUDY OF SCHISTOSOMIASIS VECTOR SNAIL POPULATION ECOLOGY

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7.1 Introduction

Mark-recapture techniques are frequently used in studies of animal population ecology, and the techniques are often more generally familiar; bird-banding and the radio-tagging of large mammals are well known examples. Mark-recapture methods have also been applied to a wide variety of invertebrate populations, both aquatic and terrestial, but despite this they have received only sporadic attention for the study of schistosomiasis vector snail populations; Fenwick and Amin (1982) established the feasibility of mark-capture methods for work on Biomphalaria pfeifferi in Sudan (see also references within) and Marti (1985) made use of marked Bullinus globosus for studying their dispersal in Tanzania.

This paper briefly reviews the type of ecological information that may be obtained by using mark-recapture techniques, discusses the value of this information for vector snail control, describes the methodology, and provides some examples of applications of the techniques to the vector snail populations in Zimbabwe. The methods and examples described below are taken from current work on the population ecology of B.pfeifferi, intermediate host for intestinal schistosomiasis, in the high veld of Zimbabwe.

7.2 Applications and relevance

Mark-recapture methods may be used to investigate:

(i) absolute abundance or density;

(ii) rates of gain (births + immigrations) and loss (deaths + emigrations);

(iii) movement.

All of these can be studied within field populations.

More traditional methods of estimating snail abundance, eg scoops, passive trapping, timed counts, can only provide relative measures of abundance. These "fractional" methods are of greatest value for following abundance trends in time at a single site. Comparisons across sites are of doubtful validity, especially when the sites comprise different habitats, and fractional methods may prove difficult to standardize across observers. The alternative of exhaustive sampling tends to be labour intensive and destructive of the habitat. Mark-recapture techniques may thus be useful for measuring absolute abundances for comparisons across sites; they are also likely to be less subject to observer effects. Absolute abundance estimates are also necessary for the calculation of transmission coefficients (eg schistosomiasis incidence per infected snail per week) and for use in transmission dynamics models; it is more biologically meaningful to deal in units of snails per m^2 than snails per 100 seconds search time or snails per scoop.

Estimates of gain and loss rates for field populations are essential to predict snail abundance changes. Previously birth and death rates have been estimated for laboratory populations (eg Shiff, 1964) or by analysis of size/age distributions (eg Sturrock & Webbe, 1971). Values obtained by these methods can only tentatively be applied to the field situation and neither allows for the effects of immigration and emigration. Mark-recapture methods estimate gain and loss rates directly for the population in question; though basic designs do not distinguish birth/death from immigration/emigration.

Snail movement can also be studied directly, both small scale active dispersal and large scale passive dispersal, which may occur during the rainy season. I will not, however, discuss these applications here.

An additional advantage of mark-recapture methods is that they can estimate standard errors for population parameters, providing an objective assessment of the precision of the results.

7.3 Methods

The following protocol has been used successfully in studies of B.pfeifferi and B.globosus populations and is adapted from that used by Fenwick and Amin (1982).

(a) Capture

Ideally snails should be sampled at random from a delimited area. We have sampled using snail scoops with a 2mm mesh, thus capturing snails down to 4-5mm diameter/length, at 1-2 scoops per m^2 in shallow pools and 1-2 scoops per metre of bank in rivers, having established that snails are rare on the river bed itself. Less comprehensive sampling, eg at a few fixed locations, is not satisfactory; snails readily move 4-5m in a few days and hence may move in or out of the study "area", reducing recapture rates and inflating estimates of gain and loss rates. It is therefore important that within the defined study area the entire snail habitat is sampled. Note also that since gains and losses include snails moving across the boundaries of the study area these boundaries should be selected with care.

(b) Marking

We mark snails using 'Cutex' nail varnish. This is applied to the cleaned, dried shells over the whorls and allowed to dry. Snails are kept on moistened tissue paper to prevent dehydration. Nail varnish must not be allowed to enter the aperture. Three colours can be applied even to snails only 5mm in size.

(c) Release

Marked snails should be released through the entire habitat if possible but care must be taken that released snails are not washed out of the study area. We therefore release snails only where the current is slow.

(d) Recapture

Snails should be recaptured using identical methods to those of the original sampling. All dead snails should be ignored. The interval prior to recapture depends on the objectives of the study. For a single population estimate the interval should be the minimum time for marked and released snails to mix with the unmarked population; this may be as little as two days. Gain and loss rates should be estimated over a biologically meaningful period of time; a minimum of seven days is suggested. Longer intervals will result in a reduced recapture rate.

The above protocol does not appear to introduce any of the following biasses, the bane of mark-recapture studies, to a significant extent.

(i) Loss of marks

Caged snails lose their marks at the negligible rate of 0.01 per week over the first week.

(ii) Differential mortality

Caged marked snails show no increase in mortality rates compared with unmarked snails caged immediately after capture.

(iii) Differential predation

Preliminary studies indicate no differential mortality between snails marked with different colours nor between varnished snails and those marked by piercing the shell with a pin. This implies that any effects due to predators being attracted or repelled by the marks are also negligible.

The main potential difficulty is non-random sampling of the population. The sampling method should not rely on vision so as to prevent preferential capture of marked snails. However, it may be difficult to sample equally from all sub-habitats within the study area; this effectively means that some snails may be more easily captured than others, so biassing the results. Certain experimental designs allow this bias to be estimated and allowed for, (Woolhouse, in prep).

7.4 Design and analysis

Various possible designs for mark-recapture studies are reviewed by Begon (1979). The simplest is the Petersen estimate of absolute abundance but I will discuss the least complex design that allows estimates of gains and loss rates as well, Bailey's triple catch design.

After the initial marking and release two recaptures are needed: on the first of these previously marked snails are marked using a distinct colour; on the second recapture snails marked on one of the two previous occasions can be distinguished. No snail should be marked twice (but see Woolhouse, in prep). Previously marked snails should be re-released. The time intervals between the three sampling trips need not be identical. The following data should be recorded:

Number of snails marked originally (time t=0)	M_0
Total snails caught on 1st recapture (t=1)	n_1
Number snails marked at time 0 recaptured at 1	m_{01}
Number snails marked at time 1	m_1
Total snails caught at 2nd recapture (t=2)	n_2
Number snails marked at time 0 recaptured at 2	m_{02}
Number snails marked at time 1 recaptured at 2	m_{12}

These data can be summarised as follows:

Time	Number captures	Number marked	Recaptures marked at t=0	Recaptures marked at t=1
0		M_0		
1	n_1	M_1	m_{01}	
2	n_2		m_{02}	m_{12}

The total number of snails in the study area at time t=1, N_1, is given by:

$$N_1 = \frac{M_1(n_1 + 1)m_{02}}{(m_{01} + 1)(m_{12} + 1)}$$

Formulae for the standard error of N and for the gain and loss rates and their standard errors are given in Caughley (1977). Recall that gains = births + immigrations and losses = deaths + emigrations and that both apply to snails of at least 5mm diameter/length ("births" is therefore more properly referred to as recruitment). The gain rate is estimated between t=1 and t=2 and is the multiplicative increase over that interval, ie a gain rate of 1.0 is equivalent to no births or immigrations. The loss rate is estimated between t=0 and t=1 and is 1 - survivorship over that interval, ie a loss rate of 0.0 is equivalent to no deaths or emigrations. Note that sampling error may result in "impossible" estimates of gain rates below 1.0 or loss rates below 0.0, which should be interpreted as no gains and no losses respectively.

7.5 Examples

1. Bushu: B.pfeifferi in a slow-flowing shallow pool (depth less than 1m) of area 100m^2. 1 scoop per m^2

Date	Number Captures	Number Marked	Recaptures 1st mark	Recaptures 2nd mark
12/6/86		397		
19/6/86	653	445	59	
26/6/86	469		34	53

Absolute abundance (19/6) = 3054 ± 756
Gain rate (19-26/6) = 1.213 ± 0.251
Loss rate (12-19/6) = 0.294 ± 0.155

This indicates high snail abundance (approximately 30 per m^2 - this value is supported by a capture rate of approximately 7 snails per scoop) a low gain rate but a significant loss rate; the population is apparently decreasing by 14% per week. These results are as expected for a snail population at the start of the cold, dry season.

2. Chiweshe: B.globosus in a moderate-flowing river (depth up to 2m, width up to 5m). Both banks sampled at 2 scoops per m for 840m.

Date	Number Captures	Number Marked	Recaptures 1st mark	Recaptures 2nd mark
31/7/86		277		
7/8/86	309	283	26	
14/8/86	359		15	23

Absolute abundance (7/8) = 2024 ± 722
Gain rate (7-14/8) = 1.89 ± 0.52
Loss rate (31/7-78) = 0.36 ± 0.21

This indicates moderate snail abundance (1.2 snails per m bank) with appreciable gain and loss rates, with the population showing an overall increase of 21% per week. This appears high for a population at the end of the cool, dry season though the increase is supported by the observation of small (ie young) snails in the samples; but note the wide confidence limits on the estimates, a consequence of the relatively small sample size.

7.6 Sample sizes

The preceding examples provide an idea of the sample sizes necessary to obtain population parameter estimates to a given level of precision. A more detailed indication of the required sample sizes is provided in the following table. This shows the coefficient of variation (CV) of parameter estimates based on a given number of snails captured, n, and the proportion of marked snails recaptured, m/M. For simplicity gain and loss rates are assumed to be negligible and a constant number of snails are captured on each sampling occasion. A CV of less than 0.25 would normally be desired.

	n					
m/M	10	50	100	500	1000	5000
.01	-	-	1.00	.64	.49	.24
.02	-	1.00	.85	.49	.37	.17
.05	-	.80	.65	.33	.24	.11
.1	1.00	.66	.51	.25	.18	.08
.2	.84	.52	.38	.18	.13	.06
.5	.71	.37	.28	.13	.09	.04

If m/M is known, eg following a pilot study, then the above table can be used to suggest the required sample size. Sample size depends on snail density, the area of the study site, and the intensity of sampling, eg number of scoops per metre. For example 1 above, the proportion of marked snails recaptured is about 0.12, suggesting a sample size of at least 400 snails. For example 2, the proportion is 0.9, suggesting a sample size of at least 600, which was not in fact achieved.

7.7 Evaluation

Mark-recapture methods for vector snail population ecology studies have several potential disadvantages:

(i) they require large numbers of snails to provide precise parameter estimates;

(ii) they are both labour and effort intensive;

(iii) they require trained personnel for both implementation and analysis.

As such it is not recommended that a mark-recapture program be initiated without pilot studies to determine feasibility nor without consideration of alternative methods; relative abundance measures may be adequate for some purposes. If, however, it is considered necessary to obtain estimates of absolute abundances and/or gain and loss rates then mark-recapture is likely to be the best available route to obtaining this information in the field.

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