The Development of Effective Community Water Supply Systems Using Deep and Shallow Well Handpumps

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EXECUTIVE SUMMARY

INTRODUCTION

Handpumps are already used extensively all over South Africa for community water supplies. In some areas these pumps, or additional ones, are also used for livestock watering and even micro industries such as brick-making. Yet, despite the fact that boreholes equipped with handpumps are among the simplest of community water supply technologies, much of the investment has been very ineffective in providing for the basic needs of these people because of high failure rates.

At any time, approximately 50% of the pumps installed for these dependent communities are not working. Often the users cannot even find out if the failure is due to the borehole drying up or to a mechanical pump failure. Of the pumps that are working, the majority are in extremely poor condition, causing long priming times in the morning and continued low delivery rates thereafter. The reason for the low delivery rates is not always clear. Pump handles have often been replaced by improvised ones, are loose at the point of attachment and have bearings that are worn right through. When pumps fail completely, it is often several months before they are repaired. The atrocious availability and performance are due to poor borehole development, inadequate pump design, poor pump selection and installation and, above all, completely inadequate monitoring and maintenance.

Water quality from many of the installations is poor. Sometimes the poor water quality is due solely to contamination caused by corrosion products leached from an incorrectly selected borehole pump and/or casing material.

International experience has demonstrated that high failure rates are not inevitable and that handpump installations can be transformed into effective reliable low-cost solutions through the systematic adoption of appropriate design technologies and implementation policies. A key factor in achieving this transformation, as motivated and reported by the World Bank, has been the adoption of the **VLOM** concept for the provision of these handpumps. This concept starts with the selection of handpumps specifically designed for **Village Level Operation and Maintenance** and extends to the whole question of the benefits of community participation, management and ownership, the training and employment of community operation and maintenance technicians, and the reduction (but not elimination) of the communities' dependence on external support systems.

The latest information available from the Department of Water Affairs and Forestry (DWAF) indicates that there are approximately 18 million people living in South Africa without access to a basic safe water supply, as defined by the RDP minimum level of service (DWAF, 2000), and that at current rates of investment it will take between 25 and 40 years to bring these people up to this minimum adequate level of service (DWAF, 1999). For health reasons alone, there is an urgent need to make **an improved water supply to the maximum number of people in the minimum period of time** a major national goal. On the basis of requiring the shortest lead time and lowest total monetary investment, the handpump option is probably the best current choice for an intermediate improved level of service for at least-one third of the 18 million people currently with an inadequate water supply.

It is therefore of vital importance that handpump manufacturers, suppliers, users, planners and project implementation agencies have access to up-to-date comprehensive information on the strengths and weaknesses of handpump installations and how the **VLOM** concept can and should be implemented.

AIMS

The aims of the research project were therefore to propose a strategy for overcoming these diverse problems in a cost-effective manner in order to improve the effectiveness of handpump installations in meeting community needs nationwide.

With these aims in mind the work was planned in two phases.

The aim of phase 1 was to review the situation in South Africa by:

- establishing the essential requirements for effective handpump installations,
- evaluating current practices to highlight problem areas,
- assessing the economics and effectiveness of centralised maintenance, and
- evaluating the handpumps currently available in South Africa and the back-up service provided by suppliers.

The aim of phase 2 was to formulate a cost-effective strategy for overcoming the key organisational and technical problems highlighted during phase 1. This was done by:

- assessing the potential of VLOM pumps for use in South Africa, such as the SKAT Afridev, the India Mark III and the Netherlands Volanta, and
- assessing the potential for training community-based operation and maintenance personnel and for introducing community management of maintenance.

The research succeeded in taking account of these objectives and has resulted in this report which comprises the following chapters:

- a literature survey supplemented with information obtained from handpump suppliers and personal communications,
- an overview of South African handpump installations and an analysis of records of groundwater levels and corrosiveness, and borehole recovery rates,
- the results of a survey of handpump stakeholders comprising a survey of South African handpump manufacturers, a worldwide survey of handpump purchasers and a survey of handpump users in rural villages from the Southern District of Northern Province, South Africa,
- a description of the planned test-rig evaluation of handpumps, and
- a discussion of the previous sections leading to conclusions and recommendations.

MAJOR FINDINGS

The literature survey was done to highlight the critical constraints impeding effective service delivery and to check how others had solved them. Technical problems reported were more extensive than anticipated. Whilst practical solutions were usually given, the occurrence of these problems does stress the need for careful project implementation and the systematic checking of site-specific criteria as implementation proceeds. The criteria to be checked are set out in five boxes in the final chapter of the report. Soft issues related to community participation and empowerment, skills training, cost recovery, transparency, the setting-up of a proper spares network and the building of capacity in decentralised institutions were also reported in the literature. The need for ongoing monitoring of village-level institutions was not stressed but appears to be essential for long-term effectiveness.

The in-depth analysis of borehole and handpump installation records was done to determine the extent to which the different critical constraints highlighted from the literature apply in South Africa. The analysis confirmed that they all apply. In addition, there is strong evidence that daily water level drawdown during pumping causes the average depth from which water is pumped in South Africa to be significantly greater than in the rest of the world.

The survey of different stakeholders was done to achieve better problem definition, to learn from the experience of others and to examine conflicting evidence before proposing a plan of action to implement effective community water supply systems using handpumps. The survey of South African manufacturers established that they make robust products in adequately equipped facilities to comprehensive quality control procedures. However, despite the urgent need as evidenced by all the other sections of this report, none make handpumps incorporating VLOM concepts or corrosion-resistant materials. This appears to be due to purchasers' buying on price alone and without an adequate specification. The survey of handpump purchasers revealed that most understand what is required to produce more effective installations. However, in contrast to purchasers from outside South Africa, local purchasers generally had a very negative attitude towards handpumps, which must lower their motivation to strive for improved installations.

Users made it clear that they appreciated the handpumps in their villages (when they worked). The alternatives, buying water from vendors, using unsafe water from rivers, relying on springs that dried up every winter and digging in river beds in search of clean water, all gave the users an appreciation of the benefits of village handpumps. As well as using them for domestic water supplies, the majority of communities use their handpumps for at least one other purpose: livestock watering 47%, community gardens 33% and building 13%. This indicates the importance of ensuring the effectiveness of handpump systems until they are upgraded to a higher level of service.

However, this appreciation should not be confused with satisfaction. Varying levels of dissatisfaction and unrealistic demands will still be the norm until users understand the costs associated with other options and see equitable tariffs more closely related to these costs being introduced systematically throughout their region for those who can afford them. In addition many communities fear that making handpump systems more effective will jeopardise their hopes of obtaining a higher level of service later. All communities want to know that they are being heard with consideration. A synthesis of their comments on what is required to provide an effective service using handpumps follows.

"Check the quality of the water before deciding if and how the borehole is to be fitted out. Improve the delivery rate of the pumps; this includes ensuring good preventative maintenance. Make the pumps more reliable. Above all shorten the time for repairs. Put in more pumps closer to our homes; this will cut down the walking and queueing times, and will also reduce the number of breakdowns because the pumps will not have to work so hard."

RECOMMENDATIONS

The consolidated findings from the literature survey, the analysis of borehole and handpump installation records, and the surveys of handpump stakeholders indicate that three broad areas of project implementation have to be carried out competently to achieve effective community handpump systems. The three broad areas are:

- the development of the borehole and the measurement of recovery rates,
- the selection and installation of the handpumps, and
- ensuring adequate village, local government and private enterprise institutional and skills capacity.

The three broad areas of handpump project implementation can be broken down into greater detail as follows:

The borehole

- Select drilling positions with the future customers.
- Check that the water quality is fit for purpose - health, taste and colour.
- Check if the borehole should be developed by over-pumping, intermittent pumping, backwashing or surging.
- Check the borehole pumping yield and recovery rates for different drawdown depths by doing a simple constant drawdown and recovery-from-drawdown test.
- If the recovery rates are all very low consider hydro-fracturing, and retest if hydro-fracturing is carried out.
- Check for indications that the water may be abrasive - if yes, select suitable filter packing to be used outside the well casing to minimise such abrasion.
- Check for indications that the water may be corrosive - if yes, use a uPVC casing material.

The handpump

- Check the preferences with future customers.
- Check the need to consider the corrosiveness of the water.
- Check the pump's likely future operational duty point by looking at the intersection of a good handpump's QH curve with the borehole's recovery rate curve.

- Check if the demographic area has already standardised on a VLOM pump which satisfies the three criteria described immediately above.
- If yes, buy the standardised pump. If no, write a specification for a suitable VLOM pump covering the three criteria described above. Buy against specification: never buy on price alone.
- Select a suitable pump platform to cater for all customer ergonometric and hygiene needs.
- Install the pump in a manner which allows the level of the water in the borehole to be measured without removing the pump. The level measuring area must normally be sealed off.

The institutional requirements

- Local water authorities and their agents need to have a positive attitude towards handpump installations.
- Before installing the handpumps, ensure that the location and number of handpumps installed is acceptable to the customers. The daily demand from each pump should be supplied in five hours.
- Having sufficient village level institutional capacity and technical skills for the day-to-day care of the installed handpumps is critical. Instruction books for monitoring the borehole and caring for the pumps must also be available.
- An equitable cost recovery system managed transparently by village level institutional structures is also critical.
- Sufficient local government capacity to monitor village-level institutions and manage major maintenance work is needed.
- Sufficient capacity needs to be built up locally to carry out major maintenance work.
- A proper spares network needs to be set up.

CONCLUSIONS

The project results clearly highlight what is required for the development of effective community water supply schemes using deep and shallow well handpumps. Despite the South African focus, the majority of the findings apply universally. The report also gives comprehensive details on how to implement the majority of the micro recommendations. For example, the report explains how to carry out a simple borehole recovery test, how to use the test results to draw a curve indicating the recovery rate at different drawdown depths and, finally, how to use the curve to help with the selection of a suitable handpump. Having demonstrated clearly that VLOM pumps do play an important role in the implementation of cost-effective sustainable projects, the report goes on to indicate that choosing the correct VLOM pump is still critical.

More countries around the world are paying attention to such technical details and critical socio-economic factors. The results can be seen in the improved percentage of pumps operable at any time.

However, in South Africa, in most areas of the Eastern Cape, KwaZulu-Natal and Northern Province this is not happening and the situation is critical. In neighbouring Botswana and Lesotho the standard of domestic water supplies is high but handpump installations seem to have been left out of the thrusts which achieved these impressive standards. Mozambique recently embarked on an ambitious programme of water delivery to rural areas using handpumps. However, there have been problems, many of which could be solved using the findings of this report.

The strength of the report lies in the manner in which it integrates information from diverse sources and comes to new insights through dealing with the borehole, the handpump and the community's circumstances as a single entity. Also innovative is the extent to which it encourages a structured analysis of situations before deciding on a definitive course of action. These comments are particularly true in cases where, up to now, community and local government empowerment have been weak and/or water is to be lifted from deep boreholes with low recovery rates. Other aspects covered comprehensively are abrasion and corrosion.

RECOMMENDATION FOR FURTHER RESEARCH

In the course of the study it was established that the majority of technical challenges in relation to requirements for the development of effective community water systems using deep and shallow well handpumps have been solved.

There are however still two outstanding queries with respect to the suitability of handpumps fitted with uPVC riser mains to handle pumping heads in excess of about 35 m . The test-rig built and partially commissioned as part of this study would be ideally suited to finding an accurate answer to one of these queries, namely: how effective riser main centralisers are in arresting elastic deformations in such riser pipes, which cause a major reduction in discharge rates at high heads. The second query is: how effective are such centralisers in overcoming the fatigue failures experienced with such riser pipes at high heads? It can reasonably be inferred that if such centralisers reduce the elastic deformations to the extent that they no longer affect the discharge rate they will also overcome the problem of fatigue failures. Thus using the test rig for such testing would provide answers to these questions.

The rig could also be gainfully used for speedily increasing our knowledge of the pumping rates that can be achieved by users of different types and makes of handpumps at different water levels, and for checking and perfecting the performance characteristics of new pumps.

Lastly uPVC riser pipes are difficult to manage during pump installation and, where necessary, abstraction because of the use of solvent cement site joints. Some research needs to be done to perfect a viable alternative. SKAT of Switzerland, together with Preussag of Germany, and/or Van Reekum Materials of the Netherlands, are ideally suited to carry out this work.

Other information gaps would be best met through the activities described below.

RECOMMENDATION FOR TRANSFER OF RESULTS

The report ends with recommendations on how to transfer the results of the study into best practice in the field. This requires two basic activities:

- the revision or writing of certain technical specifications, and
- the implementation of demonstration projects, with the support of a national coordinating organisation to ensure that these projects act as a catalyst for countrywide replication.

There are still information gaps. Most of these relate to the need to supplement qualitative findings contained in this study with more detailed quantitative information. The proper implementation of the proposed demonstration projects, together with the encouragement this will give for accurate borehole installation monitoring throughout South Africa, would fill these gaps and over time dramatically improve the effectiveness of community water supply systems using handpumps on deep and shallow wells.

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The development of effective community water supply systems using deep and shallow well handpumps

The Steering Committee responsible for the project consisted of the following persons:

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Ms U Wium	Water Research Commission (Committee Secretary)
Mr IMV Ngwenya	Umgeni Water
Mr AS van Niekerk	Agricultural Research Council
Mr BL Venter	Department of Water Affairs and Forestry
Mr JS van Blerk	Department of Water Affairs and Forestry
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Mr J Rissik	Stewarts & Lloyds
Mr MG Rall	Mvula Trust

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ABBREVIATIONS

ARC	Agriculture Research Council, Silverton, Pretoria, South Africa
C	degrees Centigrade
$CaCO_3$	calcium carbonate
CATR	Consumers' Association Testing and Research laboratories, Hertfordshire, England
CSIR	Council for Scientific and Industrial Research, South Africa
DCD	Department of Constitutional Development
Difs	differences
DWAF	Department of Water Affairs and Forestry, South Africa
FAO	Food and Agricultural Organisation
Fe	iron
GDP	gross domestic product
GI	galvanised iron
GNU	Government of National Unity, South Africa
GRP	glass reinforced polyester
hr	hour
HDPE	high density polyethylene
HTN	Handpump Technology Network
H_2O	water
IDRC	International Development Research Centre, Canada
IRC	International Research Centre, The Netherlands
k	a constant
kg	kilogram
ℓ	litre
m	metre
min	minute
min t	minimum thickness
mg	milligram
mg F/ℓ	milligrams of fluorides per litre
mg N/ℓ	milligrams of nitrates per litre
mm	millimetre
MPa	MegaPascal
MT	Mvula Trust
m/s	metre per second
NGL	natural ground level
No	number
N/mm^2	Newton per millimetre squared
OD	outside diameter
O&M	operation and maintenance
PVC	polyvinyl chloride
QH curve	quantity-head curve
R	Rand
RDP	reconstruction and development programme
rpm	revolutions per minute
RSA	Republic of South Africa
s	second
SADC	Southern African Development Community
SKAT	Swiss Centre for Appropriate Technology
SS	stainless steel
St no	statement number
TBVC	Transkei, Bophuthatswana, Venda and Ciskei
UNICEF	United Nations Children's Fund
ULGS	Unified Local Government Service, Botswana
uPVC	unplasticised polyvinyl chloride
US$	United States of America Dollar
VLOM	village level operation and management/maintenance
VAT	value added tax
WHO	World Health Organisation
WRC	Water Research Commission, South Africa
Zn	zinc
~	approximately
°C	degrees Centigrade
>	greater than
/	per
%	percent

1 INTRODUCTION

1.1 Motivation

Handpumps are already used extensively all over South Africa for community water supplies. In some areas these pumps, or additional ones, are also used for livestock watering and even micro industries such as brick-making. Yet, despite the fact that boreholes equipped with handpumps are among the simplest of community water supply technologies, much of the investment has been ineffective in providing for the basic needs of these people because of high failure rates.

At any time, approximately 50% of the pumps installed for these dependent communities are not working. Often the users cannot even find out if the failure is due to the borehole drying up or to a mechanical pump failure. Of the pumps that are working, the majority are in extremely poor condition, causing long priming times in the morning and continued low yields thereafter. The reason for the low yield is also not always clear. Pump handles have often been replaced by improvised ones, are loose at the point of attachment and have bearings that are worn right through. When pumps fail completely, it is often several months before they are repaired. The atrocious availability and performance are due to poor borehole development, inadequate pump design, poor pump selection and installation and, above all, completely inadequate monitoring and maintenance.

Water quality from many of the installations is poor. Sometimes the poor water quality is due solely to contamination caused by corrosion products leached from an incorrectly selected borehole pump and/or casing material.

International experience has demonstrated that high failure rates are not inevitable and that handpump installations can be transformed into effective, reliable, low-cost solutions through the systematic adoption of appropriate design technologies and implementation policies. A key factor in achieving this transformation, as motivated and reported by the World Bank, has been the adoption of the **VLOM** concept for the implementation of these handpump systems. This concept starts with the selection of handpumps specifically designed for **Village Level Operation and Maintenance** and extends to the whole question of the benefits of community participation, management and ownership, the training and employment of community operation and maintenance technicians, and the reduction (but not elimination) of the communities' dependence on external support systems.

The latest information available from the Department of Water Affairs and Forestry (DWAF) indicates that there are approximately 18 million people living in South Africa without access to a basic safe water supply, as defined by the RDP minimum level of service (DWAF, 2000), and that at current rates of investment it will take between 25 and 40 years to bring these people up to this minimum adequate level of service (DWAF, 1999). For health reasons alone, there is an urgent need to make **an improved water supply to the maximum number of people in the minimum period of time** a major national goal. On the basis of requiring the shortest lead time and lowest total monetary investment, the handpump option is probably the best current choice for an intermediate improved level of service for at least one-third of the 18 million people currently with an inadequate water supply.

It is therefore of vital importance that handpump manufacturers, suppliers, users, planners and project implementation agencies have access to up-to-date comprehensive information on the strengths and weaknesses of handpump installations and how the **VLOM** concept can and should be implemented.

1.2 Aims

The aims of the research project were to propose a strategy for improving the effectiveness of handpump installations in meeting community needs in a cost-effective manner.

The work was planned to be carried out in two phases.

The aim of phase 1 was to review the current situation in South Africa, by:

- establishing the essential requirements for effective handpump installations,
- evaluating current practices to highlight problem areas,
- assessing the economics and effectiveness of centralised maintenance, and
- evaluating the handpumps currently available in South Africa and the back-up service provided by suppliers.

The aim of phase 2 was to formulate a cost-effective strategy for overcoming the key organisational and technical problems highlighted during phase 1. This was to be done by:

- assessing the potential of VLOM pumps for use in South Africa, such as the SKAT Afridev, the India Mark III and the Netherlands Volanta, and
- assessing the potential for training community-based operation and maintenance personnel and for introducing community management of maintenance.

1.3 Implementation process and structure of report

During implementation some of the questions asked and the answers developed during phase 1 of the project had to be reworked because of conflicting evidence uncovered during phase 2. In the course of this reworking the distinction between the two phases became blurred and in the report the findings of the phases are merged.

The chapters of the final report comprise:

- a literature survey supplemented with information obtained from handpump suppliers and personal communications,
- an overview of South African handpump installations and an analysis of records of groundwater levels and corrosiveness, and borehole yields,
- the results of a survey of handpump stakeholders - manufacturers, purchasers and user communities,
- a description of the planned test-rig evaluation of handpumps, and
- a discussion of the previous chapters leading on to conclusions and recommendations.

Long records which would interrupt the flow of the report have been placed in appendices.

2 LITERATURE SURVEY

2.1 Introduction

The purpose of conducting a literature survey was to establish to what degree the VLOM approach addresses the problems associated with community handpump installations. Reports and journal articles relating specifically to India, Africa and South America as well as more general reports synthesising experience from developing countries were consulted. The literature confirms that VLOM handpumps are widely used in many countries and that they have contributed towards solving problems related to the use of handpumps for community water supplies. However, achieving full effectiveness is a complex issue.

Useful information was found about important specific issues such as corrosion and pumping heads. These specific issues are dealt with in Section 2.2. However, there was little integrated evaluation of problem areas, and proposed solutions were often weak or non-existent. For example, handpumps were treated in isolation from the boreholes in which they were to be installed. For this reason the literature accessed has been supplemented with information obtained from handpump suppliers and personal communications. Information thus gathered has been woven into what follows.

After being alerted to the impact of corrosion on water quality, further investigations were made into other health issues related to the use of groundwater. The findings in this regard are reported in Section 2.3. Management and social issues are discussed in Section 2.4.

Finally, a number of important recommendations abstracted from the literature are summarised as a list of essential criteria which need to be satisfied to produce effective handpump installations. These recommendations are recorded in Section 2.5.

2.2 VLOM approach to handpump design and use

2.2.1 Introduction

"Because of the improved reliability of modern handpumps, especially for heads up to 50 metres, the availability is now mainly limited by the quality of the management and spare parts supply. However, at a large installation depth the reliability decreases strongly, mainly due to fatigue. Therefore most manufacturers only guarantee their pumps for heads up to about 50 metres" (Besselink, 1992, p. 13).

VLOM pumps have generally been designed to reduce the weight of components, in order to make routine and medium-term maintenance easier, and they are usually manufactured from non-corrosive materials. Being of modern design, they also incorporate ergonomic principles and as a result they are usually easier and more comfortable to operate.

Against these advantages, the following disadvantages have to be considered. Prices can be significantly higher. They often require more skill to install than heavier pumps with galvanised-steel rising mains because the pipe joints are not screwed and socketed but are "cemented". A further problem with cemented joints is that if it becomes necessary to remove the pump from the borehole, to refurbish the well for example, it is not possible to dis-assemble them like screwed and socketed joints.

2.2.2 International experience

The most widely known VLOM concept is the use of "open-top" cylinders, which allow the plunger and foot-valve to be withdrawn through the rising main without removing the rising main itself from the borehole. The India Mark III, manufactured to Bureau of Indian Standards (1991) specification IS 13056, and the Afridev, manufactured to the SKAT (1994) Afridev handpump specification, revision 2, are two public domain designs which follow this concept of the open-top cylinder. The former, which has a galvanised-iron threaded-and-socketed rising main, is designed for relatively non-corrosive applications and the latter, which has a solvent-cemented uPVC rising main, for corrosive applications.

Figures 2.1 and 2.2 illustrate the differences between the conventional India Mark II closed-top cylinder and the India Mark III VLOM open-top cylinder. The Afridev cylinder is similar to the India Mark III cylinder but its construction materials are different to make it suitable for use with corrosive water. Maximum specified pumping lifts for the two pumps are India Mark III: 40 m, and Afridev: 45 m.

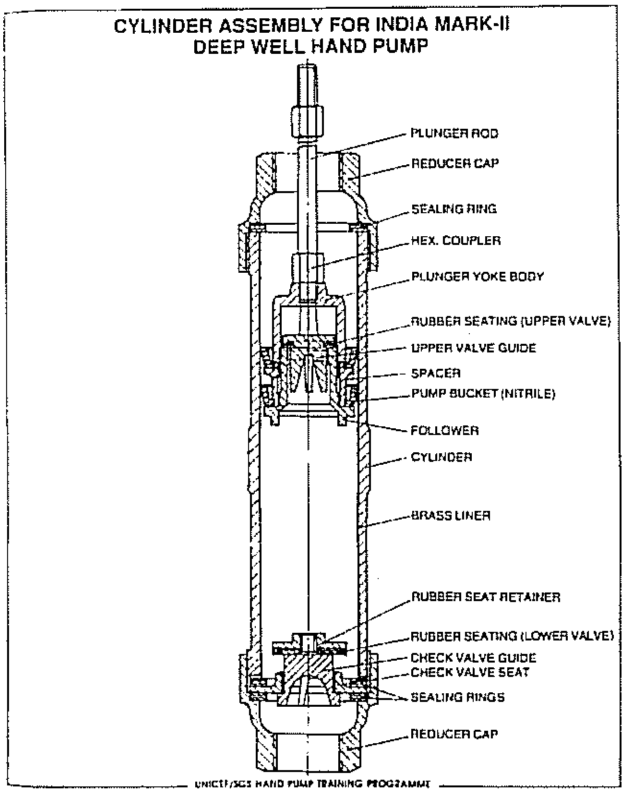


Figure 2.1: Conventional "closed-top" cylinder assembly for an India Mark II handpump (UNICEF, 1993, p. 33)

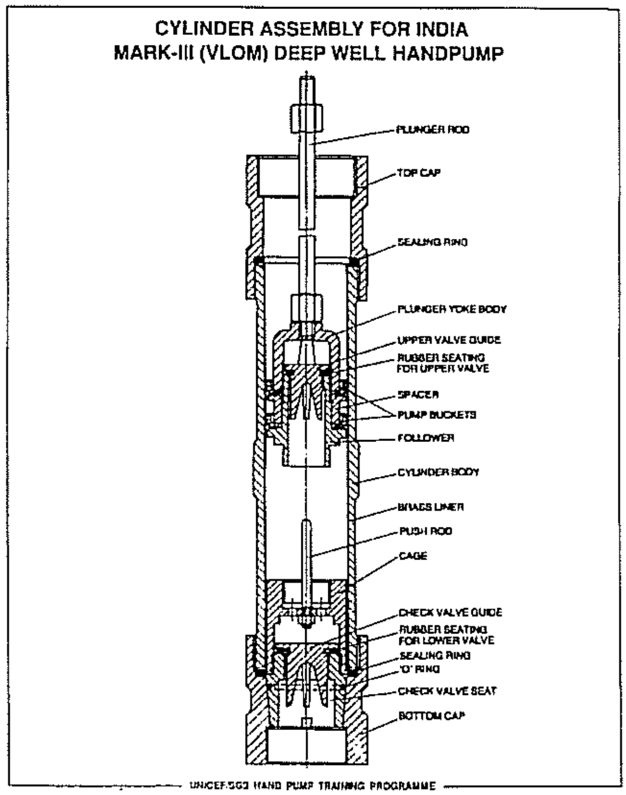


Figure 2.2: VLOM "open-top" cylinder assembly for an India Mark III handpump (UNICEF, 1993, p. 38)

Such a design presupposes that failure of the pump cylinder and the rising main must be kept to a minimum to be effective. Therefore quality control with respect to material specifications, manufacturing specifications, assembly and installation must all be of the highest standard. For the Afridev pump, which utilises a uPVC rising main, the use of rod centralisers in the rising main, and rising main centralisers in the well, to ensure that the rods do not wear through the rising main and that the rising main does not flex and rub off the well casing, respectively, are part of the design specification.

In India extensive monitoring of the Mark III pump has been carried out. The average annual maintenance and repair time for the India Mark III was 87 minutes compared with 264 for the Mark II. Parts replaced also decreased since, amongst other factors, rising mains and some other above-ground components were less prone to damage while being removed to service the piston and footvalve in the cylinder of the pump. In addition, 95% of the maintenance/repair work carried out on the India Mark

II was done by teams travelling in a vehicle with special tools. In contrast 70% of the work on the India Mark III was carried out by the village caretaker or a local mechanic travelling by bicycle or motorbike (Reynolds, 1992, pp.86-88).

Mozambique is a country with a high prevalence of corrosive water. As a result, in 1994 the government standardised on Afridev pumps for all installations with cylinder settings of less than 50 m and a little later, after experiencing frequent rising main failures with another pump fitted with a uPVC rising main, released the Afridev pump for installation with cylinder settings as great as 60 m . The Afridev specification states "the pump is suitable for lifting water from depths of 10 m to 45 m". Despite these pumps being a new technology for Mozambique, those installed with cylinder settings of less than 40 m (average setting 30,2 m) have performed well. Those installed at the greater depths (average depth 50 m), however, have had a breakdown frequency of more than 3 times that of the other units, with 63% of the breakdowns being of a non-VLOM nature and therefore requiring outside assistance to repair (Baumann, 1996, p. 2).

The literature reports that at depths in excess of 45 metres fatigue failures on the rising main may be a problem. Lastly, at similar depths, the flexibility of the rising main pipes can significantly reduce the already low output by reducing the volumetric efficiency (Besselink, 1992, p. 9).

2.2.3 Extending the benefits to high head applications

Thus, both these open-cylinder VLOM pumps, the India Mark III with its galvanised-iron rising main for non-corrosive applications and the Afridev with its uPVC rising main for corrosive applications, have proved the advantages of using VLOM pumps for pumping lifts up to about 45 m head. For higher heads, however, as can be seen from the Mozambique example, it is essential to think more broadly when choosing a VLOM pump or even a non-VLOM pump suitable for corrosive applications and to challenge Baumann's assertion (1996) that alternative pump types that would give trouble-free solutions above 45 m are not available.

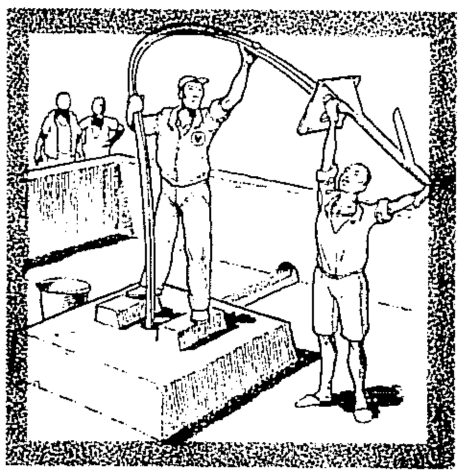


Figure 2.3: Installing or removing a pump which uses flexible HDPE piping (Vergnet, 1995, p. 2)

One possible choice is a diaphragm pump using flexible high-density polyethylene (HDPE) pipe for both the rising main and the pilot drive pipe, which is used to operate the diaphragm hydraulically. Such a pump has no pump rods and thus the entire pump, including flexible rising main and pilot, can be installed and removed quickly as shown in Figure 2.3. As the actuator of a diaphragm pump is released, and moves upwards for the suction stroke, the diaphragm contracts and allows water to enter the pump cylinder through the footvalve. On the downward forced stroke, water in the pilot pipe expands the diaphragm, closing the footvalve and forcing the water in the pump cylinder up to the surface through the rising main. (HDPE pipe stretches with time. This stretch causes problems when HDPE pipe is used at high heads for pumps with a fixed-length connection between the actuator and the pump cylinder, but is not a problem for hydraulically driven pumps, provided the design incorporates an automatic priming "top-up" system.)

Vergnet of France, who have recently appointed a full-time representative in South Africa, make a range of three diaphragm pumps: the first for pumping lifts from 0 - 30 m, the second from 10 - 60 m and the third from 50 - 100 m. The first is a direct action handpump, the second was designed as a foot-operated pump, but a lever-operated version is available from the Ivory Coast, and the third is available as a foot-operated unit only. An average human being can supply at least 50% more power through his/her feet than through his/her arms (Kennedy and Rogers, 1985, pp. 2-4), hence Vergnet's preference for foot-operated pumps, which seem especially appropriate for extra-high-lift units. In South Africa 12% of boreholes have static water levels greater than 45 m (refer Section 3.3) and an unknown additional percentage shift into the over 45 m category, because low recovery rates cause significant drawdown during pumping.

At first glance HDPE seems a surprising choice of material for pumping extra-high lifts. All the literature seems to confirm that for structural reasons alone 45 m of lift is the upper limit for pumps fitted with uPVC riser pipes, and uPVC is a substantially stronger plastic material than HDPE. The fact that the strength of uPVC is achieved at the expense of ductility and toughness may be the central cause of the problem. For example, the Afridev pump uses a 50mm OD class 16 uPVC riser pipe. Table 2.1 indicates the stresses induced in a class 16 uPVC riser pipe of a piston pump when pumping water from a depth of 45m. Both the maximum longitudinal stresses induced by the mass and the maximum radial stresses induced by the pressure are substantially less than 50% of the safe stress, which in the case of uPVC pressure piping systems already includes a 2 to 1 safety factor. It is therefore surprising that the failure rates of uPVC riser pipes increase significantly as soon as the pumping lift exceeds 45 m. The literature does not report the cause of these failures, (Stress concentrations due to the pipe or rod centralisers scuffing the pipe wall? Fatigue failure from millions of cycles of low intensity surge heads being made worse by the friction of the pipe rods against the centraliser walls?), but when failures occur at such low stress levels one does have to question the suitability of the material for the selected duty, no matter how many of the pumps have been installed worldwide.

On the other hand farmers use the same class of HDPE with submersible pumps to pump water from depths as great as 160 m and class 20 HDPE piping to pump from depths of 200 m without problems. They never use uPVC because of jointing problems and its unreliability due to a lack of toughness: HDPE, if really abused, just stretches and stretches before failure, whilst uPVC suddenly cracks and fails at some high stress point. (Farmers generally tie a nylon rope to the pump when installing HDPE riser pipes as an additional precaution and to make it easier to pull the pump out, especially when the riser pipe is full of water (Vosloo, 1998)).

Table 2.1: Total stresses in a class 16 uPVC riser pipe manufactured to SABS 966:1976 when installed on a piston borehole pump pumping water from a depth of 45 m

Pipe OD mm	Pipe min t mm	Flow area mm^2	X-sect area mm^2	Pipe mass per m kg	Total pipe mass kg	Total water mass kg	Total mass induced design stress MPa	Safe stress %
50	3,7	1425	538	0,86	38,7	64,1	3,94	19
Pipe OD mm	**Wave velocity m/s**	**Flow velocity m/s**	**Surge head m H_2O**	**Friction head m H_2O**	**Static head m H_2O**	**Total head m H_2O**	**Total head induced design stress MPa**	**Safe stress %**
50	484	0,13	13	0,0	45	58	7,46	36

Notes: 1. The mass-induced stress is a longitudinal stress and is at a maximum at the top of the borehole. It is essentially caused by the mass of the 45 m of water-filled pipe hanging out of the pumpstand above the water in the hole.
2. The stress induced by the total head is a radial stress. It is essentially at a maximum at the water level in the borehole and is highest during pumping because of the surge and friction heads. It is caused by the water in the rising main trying to flow back into the borehole by bursting through the pipe wall.
3. As per the requirements of SABS 966:1976 for uPVC pressure pipe systems, the design stress includes a safety factor of 2:1. After applying the 2:1 safety factor a safe yield stress of 21 MPa has been assumed. This safe yield corresponds to an expected life of 50 years when pumping water at 20° C.
4. The following elastic moduli were used to calculate the surge wave velocity: water 2100 N/mm^2 and uPVC 3300 N/mm^2.
5. A pump delivery of 11 ℓ/min, which equals an acceptable discharge rate when pumping from 45 m depth, has been assumed to calculate the flow velocity. Since this is an average flow velocity, the surge head has been estimated by assuming that the change in velocity is from 0 to 2 times this average velocity.

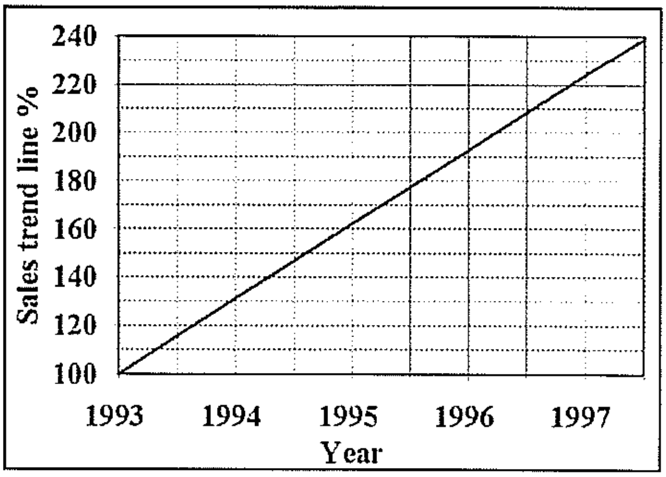


Figure 2.4: Sales trend of 100 m head Vergnet foot-operated Hydropump with HDPE riser pipes

Figures were obtained for the sales of Vergnet HPV 100 pumps in Africa for the period January 1993 to June 1998. These pumps are sold to cater for pumping water from depths of 60 to 100 m. (The medium head model of the same pump caters for heads of up to 60 m: not just up to 40 or 45 m.) As can be seen from Figure 2.4, over this period sales increased on average by just over 30% per year. With total sales in Africa being well into four figures, such an increase can only reflect satisfied customers. This is achieved with a class 10 discharge hose, which again indicates the superior properties of HDPE piping for piston handpumps, provided a suitable operating mechanism is used between the pump stand and the pump cylinder. (The drive hose is of a higher class to cater for the loading imposed by two people operating the pump by foot.)

Vergnet also provided details of the expected wear life of all components of both the HPV 60 and HPV 100 models of their Hydropump. These details have been drawn up by collating and condensing data obtained from ordinary users and spare part purchasers in the field. They are used by Vergnet for planning stockholding and preventative maintenance strategies with stakeholders. These wear life figures, which Vergnet regard as confidential, show identical periods for both models, indicating that the reliability and service requirements of the two models are essentially the same. Also received from Vergnet were certificates from clients confirming the operation of HPV 100 pumps for periods ranging from 6 to 25 months with water levels ranging from 63 to 90 m, including one pumping water from 75 m which had operated on average for 15 hrs each day for 12 months. All these pumps had operated satisfactorily for the above periods without a single breakdown. In most cases some normal wearing parts located at the surface, but only such parts, had been replaced. (Note: clients' certificates were only sought for the HPV 100 pump.)

Lastly Vergnet provided Bureau Veritas certified maximum delivery rates for their pumps, obtained from tests carried out in France. The results of these tests are shown in the first three quadrants of Figure 2.5. The HPV 30 pump, for lifts from 0 to 30 m, is hand-operated by one person like a direct action piston pump. The HPV 60 pump, for lifts from 0 to 60 m, is foot-operated by one person, and the HPV 100 pump, for lifts from 50 to 100 m, is foot-operated by two persons. The persons carrying out the tests were 1,74 m / 80 kg and 1,80 m / 90 kg. The fourth quadrant of Figure 2.5 records discharge rates for HPV 100 pumps abstracted from the client certificates discussed in the previous paragraph. These discharge rates were achieved by community members using pumps installed in their villages.

The discharge rates shown in Figure 2.5 indicate that the performance of the low-head Vergnet HPV 30 is adequate but not outstanding. The pump also appears to be very sensitive to the depth at which the cylinder is installed. An advantage is the relatively high head for which this low-lift pump can be used, but for these duties the discharge rates achievable with the HPV 60 are significantly higher. For a country standardising on Vergnet pumps, price may then be a deciding factor. Whilst it has been stated that the performance of the HPV 30 is only rated adequate, the flow rates quoted by Arlosoroff *et al.* (1987, pp. 152, 160 and 162) for direct action piston pumps tested by CATR are similar. The discharge rates shown in Figure 2.5 suggest that for higher heads Vergnet pumps are truly effective. Of particular interest are the site records in the fourth quadrant showing that one woman or child can operate the HPV 100 at 75 m head successfully. At 89 m head the discharge rate achieved by 2 women is remarkable.

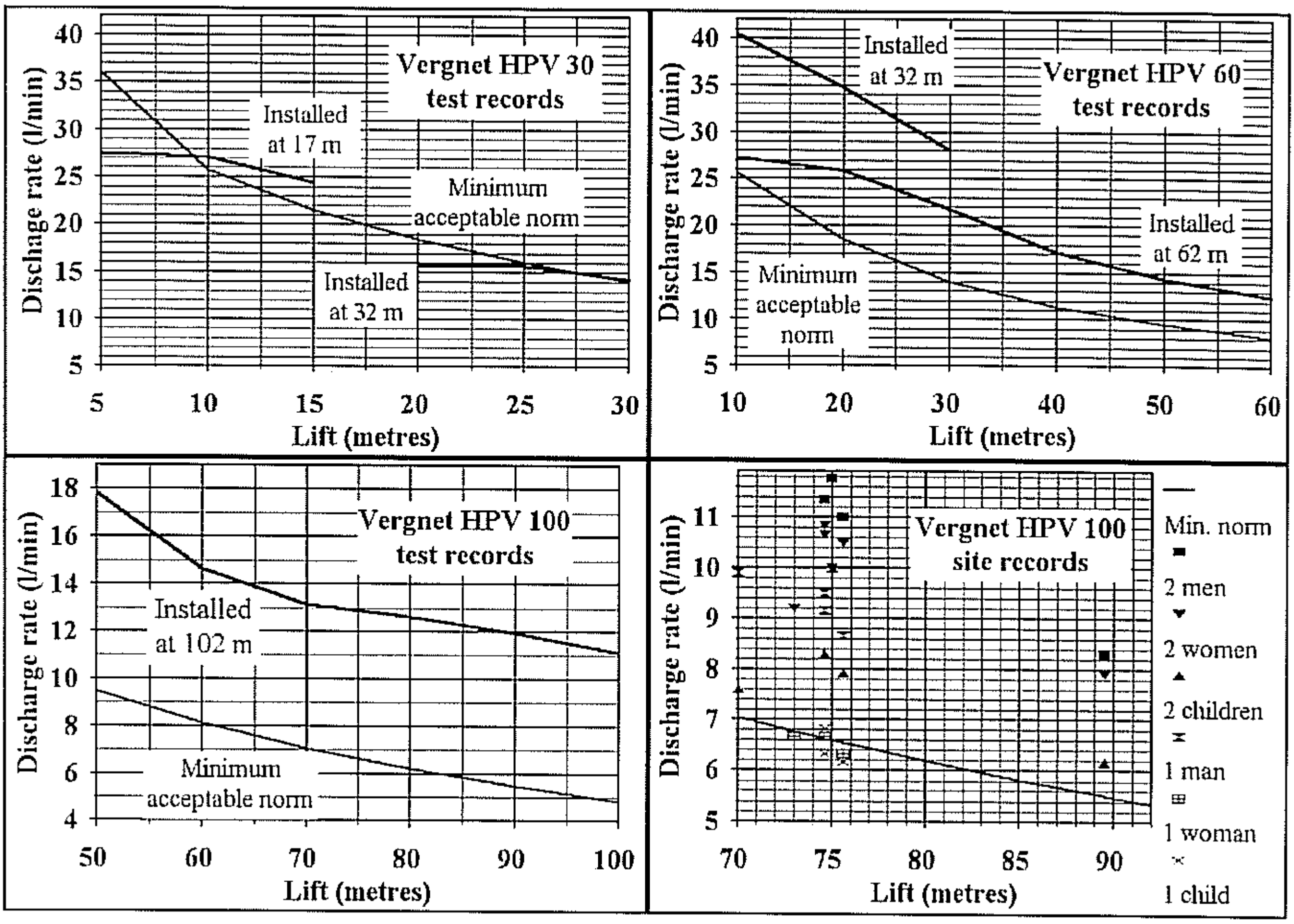


Figure 2.5: Certified discharge rates for Vergnet hydraulically activated pumps with HDPE riser pipes

Humans can generate substantially more power by using their legs/feet rather than their arms/hands. However Kennedy and Rogers (1985, p. 3) indicate that to obtain the full benefit, pedalling is required. Thus the support given for the use of foot-operated pumps in this study is based on the certified delivery rates recorded in Figure 2.5 rather than relying exclusively on theoretical considerations.

Discharge rates for other handpumps are not quoted in this report because certified figures were not obtained from the suppliers. Using CATR figures is problematic because different pumping rates (cycles per minute) are quoted for different pumps without explanation and because heads were simulated using a pressure-sustaining valve. From site reports it is evident that the use of a pressure-sustaining valve can give misleading optimistic results in the case of piston pumps with plastic riser pipes, and can have unpredictable results in the case of hydraulically operated pumps.

Standardisation plays an important role in achieving economic production runs and in reducing quality control costs to a reasonable percentage of total production costs. However, it plays an even more important role in ongoing operation and maintenance costs in terms of setting up an effective spares network and setting up and maintaining an effective decentralised network of well trained and motivated maintenance mechanics. Therefore, bearing in mind the likelihood of there being a significant percentage of boreholes in South Africa with dynamic pumping heads in excess of 45 m, the concept of standardising on a single, foot-operated, hydraulically driven, HDPE riser pipe pump is worthy of the most serious consideration. The objective of such standardisation would be to have a single, reliable, economically priced VLOM pump with good performance at all depths which is acceptable to users, in place of two VLOM pumps for heads up to 45 m, one for corrosive applications and one for non-corrosive applications, and a third VLOM pump for heads above 45 m covering both corrosive and non-corrosive applications. Just imagine all this, plus no solvent-cement joining of pipes and no pump rods to contend with.

Currently Vergnet appear to have the widest experience with respect to achieving effective rural supply systems using this option and to have the best design, through ensuring that a wide range of users, from young children to strong fully grown men, can pump water at satisfactory rates over the full range of pumping heads, and that all the wear parts are above ground. Reported disadvantages of the Vergnet are that currently it is not manufactured in a SADC country and that buying a replacement diaphragm when it fails is expensive. Countries want local manufacture for four main reasons: good back-up service, stable prices, local employment and saving foreign exchange. Human-powered pumps are core business for Vergnet. Therefore, once there are a critical number of Vergnet pumps in the country one can expect better service from them than from a company without this focus or experience in rural development.

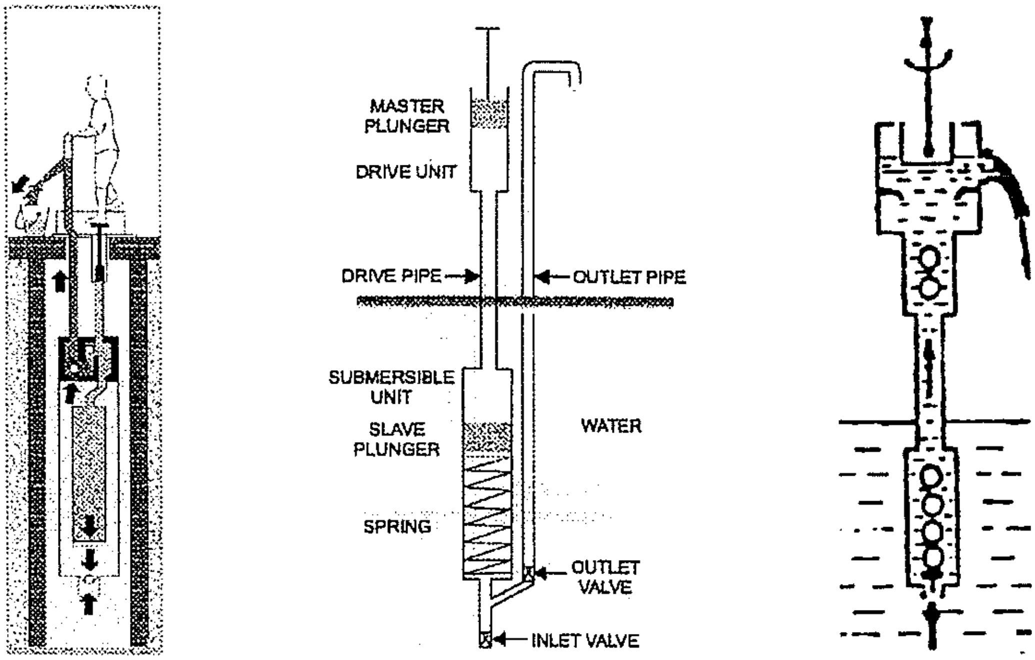
The weak Rand is a cause for concern when one makes a commitment to importing products, but the scenarios in this regard should be examined carefully. One possibility is that this is a pessimistic concern and that in the long term the Rand will be relatively strong. A second is that the Rand will continue to weaken but local manufacturing costs will be contained. This would hasten the possibility of a foreign supplier wanting to manufacture here for both local and export customers. The third scenario is that the Rand will continue to weaken but local prices will rise at roughly the same rate. From examining these scenarios one can see that financial risks are not increased by purchasing from abroad. Pumps and their spare parts represent a small percentage of water supply scheme costs. Therefore local employment and foreign exchange are not materially affected by pump and spare part sourcing decisions.

With respect to the price of a replacement diaphragm for the Vergnet pump, for any pump the important criteria are total maintenance costs and perhaps the total long-term costs of the spare parts. In terms of total maintenance costs Vergnet claim with reasonable evidence that there is "no other pump currently in use in the rural water supply sector which comes close to the Vergnet Hydropump in terms of maintenance costs" (Vergnet, 1992). The annual average cost of spares per pump quoted from countries where large numbers are being used varies from R 55-00 to R 165-00, using an exchange rate of US$ 1-00 = R 5-50.

Besides France's Vergnet pump, another pump waiting in the wings to become South Africa's first reliable, economically priced VLOM pump, with good performance and user acceptance at all dynamic heads from 10 to 100 m, is the Barry Pump. Like the Vergnet pump, the Barry Pump is a foot-operated, hydraulically driven, HDPE riser pipe pump. It was developed and patented in South Africa about three years ago and since then has been manufactured, and continuously improved in field trials. Unlike the Vergnet pump, the Barry pump has no expensive diaphragm down the hole, but this design difference has been achieved at the expense of duplicating some of the wear components of the surface mounted drive cylinder in the slave cylinder at the bottom of the riser pipe.

Additional monitoring and evaluation are required to confirm the overall effectiveness and economic value of the Barry Pump design. Latest reports from KwaZulu-Natal, where Partners in Development installed a few Vergnet pumps and a few Barry pumps about 18 months ago, indicate communities' satisfaction with the Vergnet pumps but dissatisfaction with the reliability of the Barry pumps (Still, 2000). A new hand-operated version of the Barry pump, called the Afrideep, is currently being developed. Although hydraulically driven, the Afrideep uses only one HDPE riser pipe to connect the pump cylinder to a standard Afridev pumphead (Preat and de Melo, 2000, pp. 30-31).

There is a third pump on the market using a HDPE riser pipe. It is the Pulsa pump from Italy. Like the Vergnet and Barry pumps, the Pulsa pump is hydraulically activated, but unlike the Vergnet and the original Barry pumps, it uses only one pipe to connect the above-ground cylinder with the submerged cylinder. This is achieved by using the characteristics of an oscillating column of water to transfer the operator's input power from the piston in the above-ground cylinder to elastic spheres in the submerged cylinder. During the downward stroke of the piston in the upper cylinder the spheres are compressed. As they expand again during the return stroke of the piston, the water spills out through the top of the pump and, as in a conventional reciprocating pump, water is simultaneously drawn through the suction valve. The pump is operated through a combined hand- and foot-operated lever.



Vergnet pump
foot-operated
(Vergnet, 1995)

Barry pump
foot-operated
(Barry, 1998)

Pulsa pump
combined and hand-operated
(Fluxinos, 1992)

Figure 2.6: Three makes of hydraulically activated pump, all with HDPE riser pipes

As with the Vergnet pump, the wearing parts of the Pulsa pump are all above ground. However the maximum pumping rates at low and high heads quoted in the Pulsa and Barry sales literature are lower than the corresponding certified pumping rates obtained with a Vergnet pump. Figure 2.6 illustrates the basic design of these three makes of rod-less pump with HDPE riser pipes. The individual pictures have been taken from the sales literature of the respective companies.

Apart from all the performance and ease of maintenance criteria discussed above, any hydraulically operated human-powered pump sold on the South African market must have an effective automatic top-up repriming system and have the ability to pump a mixture of air and water without, for example, additional wear or the danger of incurring a vapour lock.

Much has been said and written about the advantages of public domain designs in maintaining competition and quality standards. An alternative argument is that sellers of private domain goods are more likely to give better after-sales service than sellers of public domain products. (The different expectations of respondents within and outside South Africa with respect to the importance of the back-up service provided by the pump seller are reported in Section 4.3.9.) With the use of private domain designs, competition is maintained by potential competitors watching for a gap created by any excess profit-taking and designing improved products; and quality is maintained, if necessary, by the purchaser having an adequate specification and fitness-for-purpose guarantee in the contract. Over-dependence on public domain designs on the other hand discourages innovation.

2.2.4 Using uPVC for high head applications

Recent evidence has come to light suggesting that uPVC can be used for high head applications (van Beers, 1999b) but that the quality of workmanship needs to be much more carefully controlled than is the case with HDPE installations.

Some failures are due to faulty pipe material, caused by poor quality control during the manufacture or purchase of the uPVC pipe or through storing the finished pipe in sunlight before installation.

A second cause of failure is weak pipe joints. To achieve satisfactory joints the handpump manufacturer's instructions must be carefully adhered to. A common cause of problems is using too much sandpaper to roughen the surfaces to be joined. This results in there being too much space between the pipes and the sockets. When the glue is put on the surfaces to be joined, it melts a thin surface layer of the uPVC pipe and socket. This melting process gives a connection which is stronger than the pipe itself and will never fail. When too much sanding has been done and, as a result, there is too much space between the pipe and the socket, the connection relies on the strength of the glue only, as the pipe and socket cannot melt into each other. The resultant weak joint is particularly vulnerable if the rising main is not held in a fixed position in the borehole through the use of centralisers. The glue itself can also be a problem in that pump installers tend to buy large cans to save money. These cans get used up too slowly, are left open too long, often in the sun, and are not sealed properly after use. This causes the glue to deteriorate. To prevent this problem, glue should only be purchased in small 250 cc cans or tubes and kept firmly closed when not in use.

The most serious cause of failure is however probably due to installers not placing centralisers on the rising main to prevent snaking during pumping. This is particularly serious in large-diameter, inclined or crooked boreholes. The resultant failures are due to mechanical fatigue, wear or a combination of both. The Afridev handpump installation and maintenance manual (SKAT, 1995, p. 21) specifies one pipe centraliser every 3 m. Van Beers (1999b) comments that the 3 m has only been specified because the riser pipes are 3 m and not because this distance gives the best protection. He recommends fitting a centraliser every metre to constrain the uPVC riser at more points, regardless of the handpump make or installation depth. Fixing the riser main firmly in the borehole with frequent centralisers increases the general reliability of uPVC rising main handpumps, and prevents pipe failures, assuming the other causes discussed above have been taken into consideration.

Having centralisers makes it easier to install pumps in deep boreholes without a rig since they produce resistance which helps to stop the pipes falling down the hole. However, they also make it more difficult to remove the pump from the hole. Thus when a pipe failure occurs, due to poor pipe material or poor jointing, installers stop using centralisers even when installing a pump for the first time. Needless to say this compounds the problem rather than solving it. This is what happened in Mozambique. In November 1996, SAWA, a small Dutch consultancy that supports NGOs in technical and institutional matters, sent a note to all NGOs in Mozambique on how to install Volanta handpumps. "Only World Relief in Gaza Province acted upon the note and installed centralisers, and they have had no more problems" (van Beers, 1999b). "UNICEF installed about 400 Volanta pumps with centralisers in Angola during the 1980s, at depths ranging from 25 to 100 m. Most of them are still working after more than ten years, some without any maintenance" (van Beers, 1999a).

In response to the claim that at depths in excess of 45 metres the flexibility of uPVC rising main pipes can significantly reduce the already low output of such handpumps (Besselink, 1992, p. 9), van Beers also reports that centralisers installed every metre are truly effective in solving this problem, whilst even at every 3 metres the problem is greatly reduced (van Beers, 1999b).

In summary, therefore, it appears that, with tight quality control, the use of centralisers every metre, and adherence to manufacturers' installation instructions, uPVC rising main handpumps can be used effectively for community water supply systems. It is however essential to get everything right first time, including the development of the borehole, since removing the whole pump for major repairs or borehole rehabilitation is still a major task. Removing HDPE rising main pumps for borehole rehabilitation is usually easier.

If uPVC pipe manufacturers perfected a way of joining pipes in a reliable way which does not require solvent-cementing on site and allows dismantling of the individual pipe lengths, this would reduce the quality control required on site and some of the difficulties of removing uPVC rising main pumps from the borehole. The literature does not record any VLOM pumps using such a system even for heads below 40 m. This is possibly because the larger diameter rising mains used with VLOM pumps rule out the use of threaded pipe and sockets even with thick-walled pipe and cold-formed trapezoidal threads to minimize the effects of fatigue. The non-VLOM Kardia 50, which uses such a threaded system, has a 48 mm outside diameter by 8 mm wall thickness rising main (Preussag, 1992) whilst the solvent-cement-bonded Afridev has a 63 mm outside diameter by 4,7 mm wall thickness riser main (SKAT, 1994, p. 34).

Another possible uPVC pipe joining method is a solvent-cemented two-part coupling which slides over the outside of the pipe and has an easy method of joining the two coupling halves. The challenge in designing such a joint is to ensure that the outside diameter can still fit down the borehole. In South Africa 150 mm nominal size boreholes are more or less standard. The coupling, therefore, needs to be designed with a maximum outside diameter of 130 mm to ensure that it can be used whilst placing minimal restrictions on the type of casing to be installed in the hole. This restriction on the outside diameter of the joint probably rules out the possibility of designing such a joint for the Volanta handpump with its 90 mm outside diameter rising main. The challenge still exists to design such a coupling for other VLOM handpumps with smaller bore rising mains such as the Afridev. Preussag Germany manufacture a flanged joint for 75 mm outside diameter uPVC piping, with the outside diameter of the flanges being 135 mm (Preussag, 1993, p. 2). A similar joint for a 63 mm outside diameter rising main would therefore have an ideal diameter for South African boreholes. A screwed-and-socketed sleeved coupling used on a prototype modified SWN 81 handpump is another possibility (VRM, 1995).

2.2.5 Direct action pumps

For low-head applications, direct action pumps are generally cheaper and easier to manufacture and maintain than conventional lever- or wheel-operated handpumps, and for working heads of up to 12 or 15 m good examples have a high delivery rate, making them "popular with users" (Arlosoroff *et al.*, 1987, p. 161). Currently such pumps are not manufactured in South Africa.

Direct action pumps would be ideally suited for the hand-dug wells of Maputoland, in the north-east of KwaZulu-Natal. A local manufacturer in the Richards Bay area or even further north might be interested in manufacturing such a pump specifically for this market if it is large enough. The best known direct action pump in South Africa is the Blair pump developed by a research institute of the same name situated in Harare, Zimbabwe. For a direct action pump the Blair has a low discharge and "has not been popular with users who have experienced other handpumps, partly because of its low discharge and partly because of the difficulty of directing the flow from the moving spout into narrow-necked containers" (Arlosoroff *et al.*, 1987, p. 151). Therefore, if local KwaZulu-Natal manufacture is considered, a more conventional corrosion-resistant design should be chosen, with a discharge rate higher than that obtainable from other deep well pumps. The pump should also be reliable and easy to maintain so that the ongoing maintenance cost is also lower than for a deep well pump.

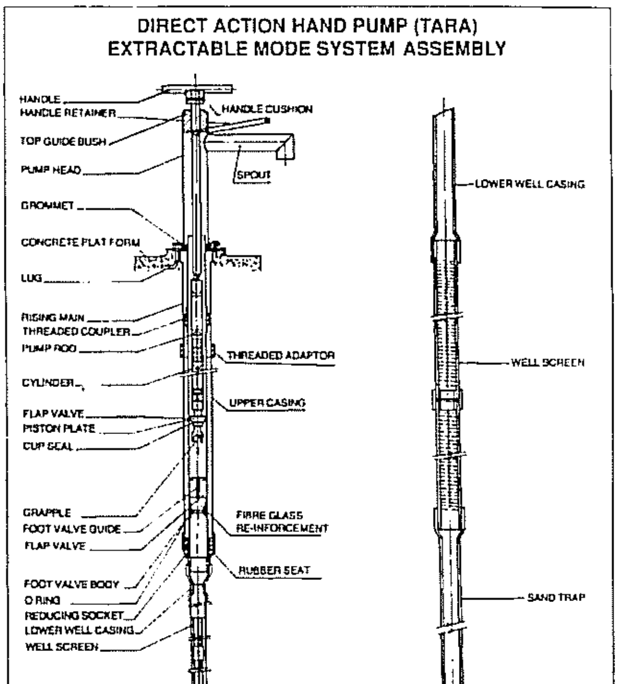


Figure 2.7: Direct action handpump with extractable cylinder, piston and footvalve (UNICEF, 1993, p. 26)

Figure 2.7 shows such a pump arranged so that the rising main is used as casing for a tube well, hence the strainer connected directly to the bottom of the pump. In KwaZulu-Natal the pump is more likely to be placed on a large-diameter hand-dug well, preferably developed to prevent the ingress of sand into the pump inlet, which is always better than any suction strainer/filter which may be fitted for extra protection.

As 30% of all wells in South Africa have static water levels of between 0 and 10 m (refer Section 3.3) it was initially assumed that a significant percentage of wells countrywide would be suitable for direct action pumps. However, because of the low yield of many of the boreholes on which handpumps are installed it is now anticipated that a high drawdown during pumping is likely to convert the majority of apparent deep well low-lift applications into intermediate-, high-, or in some cases, even extra-high-lift applications (refer Section 3.5.2). Currently there is insufficient information available to predict drawdown figures with any degree of accuracy. Overall, the introduction of direct action pumps outside the Maputo region of KwaZulu-Natal would not appear to be a high priority need. Therefore, in respect of needed technological change associated with the handpumps themselves, more focus should be placed on the selection of a VLOM pump for extra-high-lift corrosive duties, followed by an examination of the possibilities for greater standardisation, all as detailed in Section 2.2.3 above.

2.2.6 Corrosion

When selecting handpump construction materials "it is imperative to take the corrosiveness of the water into consideration. Galvanized-iron rising mains and rods, which are used for large numbers of pumps, offer no or only very little protection against corrosion and should not be used where groundwater is corrosive. The major problem is not necessarily only an increased frequency of breakdowns but certainly also a deterioration of the water quality due to corrosion products which lead to high iron concentration(s), high turbidity (red water) and bad taste. Laundry may get stained when washed with such water and food is known to change taste and colour when cooked in it. This problem makes the pump users reluctant to accept such water and may cause them to abandon the well altogether" (Langenegger, 1988, pp. 5 and 7).

When corrosion is a problem, the choice of well-casing material is likely to have an even greater effect on the deterioration of the water quality than the choice of rising main for the pump. Therefore, before choosing any permanent casing material for a borehole which may have a potential to corrode, it is essential to check the corrosiveness of the water in the hole and, if relevant, take the result into account before making a final decision (Banda, 1997).

In a telephone conversation, Mr Erich Baumann, Departmental Head at SKAT, the Swiss Centre for Appropriate Technology and co-author of the Afridev Handpump Specification (SKAT, 1994) also warned against the selection of VLOM pumps with uPVC riser pipes for high-lift applications where corrosion is not a problem. According to him, "you tend to need lifting gear anyway for installing both types of pump and for major maintenance work. The cemented joints required for rigid plastic rising main pipes as compared with screwed and socketed for galvanised iron pipes are just an unnecessary complication."

Further issues relating to the presence of iron in water are discussed in Sections 2.3.3 and 2.3.4.

2.2.7 Wear and abrasion

Most VLOM pump designs allow for the removal of the footvalve and the plunger assembly of the pump cylinder without having to lift the rising main, but it appears that, with the exception of the Volanta pump designed in the Netherlands, the pump cylinder itself remains down the borehole. However Yau (1985, p. 87) reports that wear of the pumping section of a handpump cylinder can be serious. After an 8,5 month period, 2 out of 17 pumps that were being monitored in the field had "worn through, causing water to leak through the cylinders and the cylinder walls had worn so thin that they had become flexible."

But more careful reading of Yau (1985, pp. 87-90) indicates that the pump cylinders being tested were manufactured of PVC. Further, if the pump cylinder material and plunger seal material are matched and chosen for the application, cylinder wear is no longer a problem. Plunger seals, however, remain as a wearing component, hence the importance of VLOM designs, which allow for easy access to the plunger assembly (Arlosoroff *et al.*, 1987, pp. 65 and 66). Being able to remove the whole pump cylinder remains marginally the better technical option, since this makes it possible to repolish the cylinder bore when replacing a seal and thus prolong the life of the critical wearing component, the seal.

When abrasive wear is a problem it must be taken into consideration when the borehole is being developed. Whilst standard slotted well screens are ineffective, gravel packed screens are a most effective means of overcoming pump abrasion problems. Such screens can be bought with the gravel already bonded to the screen or they can be developed by filling the cavity between a temporary outer casing and the permanent casing/screen *in situ* with a suitable gravel. Suitable gravels are of a fixed size, structurally and chemically stable, and non-corrodible. Typical grain sizes vary from 1 to 3 mm whilst the difference in diameter between the outside diameter of the permanent casing/screen and the inside diameter of the temporary casing to allow for the gravel pack should not be less than 75 mm (Banda, 1997).

2.3 Health issues related to the use of groundwater

Groundwater can generally be used for domestic water supplies and animal watering without treating it, which is often an important factor in why people choose to develop a groundwater supply rather than a surface water one. However the quality of groundwater is not always satisfactory and it is therefore still important to check that any groundwater being developed is of a safe and acceptable quality with respect to its healthiness, taste, colour, and laundry use, as well as its corrosion/scaling potential. The first four criteria listed are covered adequately, for the most part, in a WRC report published in 1993 on the cost-effectiveness of rural water supply and sanitation projects. This report (WRC, 1993) should be consulted to supplement the information given below. The likely quality of groundwater abstracted in South Africa and some general comments are described on pp. 39-40 and p. 57; safe limits on pp. 57-61; methods of testing on pp. 61-63; and treatment on pp. 64-101.

2.3.1 Bacteria and viruses

Harmful bacteria and viruses, which are usually caused by faecal pollution, can normally be kept out of groundwater by careful siting of the well (and sanitation facilities), adequate sealing of the well from surface water particularly by the construction of a suitably designed platform around the well, fencing the well off from animals, rinsing out storage containers and keeping stored water covered. Larger harmful living organisms, such as parasites, do not infect groundwater. Therefore, should any groundwater or collected and stored groundwater become infected with harmful bacteria or viruses it can be effectively and cheaply chlorinated against these living organisms with non-perfumed bleaches such as Jik or Javel (sodium hypochlorite) for small quantities or with HTH (dry granular calcium hypochlorite) for larger quantities. Chlorine tablets sold in stores for use in swimming pools are generally not suitable for disinfecting drinking water.

As harmful bacteria and viruses can normally be kept out of groundwater, if indications of such pollution are found, shock treatment by the addition of chlorine is first recommended. If further sampling indicates that the bacteria have not been permanently cleared, the source of the pollution should be found and if possible removed. Otherwise disinfection with chlorine as described above must be carried out on a continuous or semi-continuous basis.

2.3.2 Fluorides and nitrates

Other substances which can have adverse health implications are fluorides and nitrates. High fluoride levels are normally due to the natural geological formations in the area. Fluoride levels above 3 mg F/ℓ cause the teeth of people drinking the water and using it for cooking to become mottled with a permanent black or grey discolouration. At higher levels it causes poor bone development in growing children and cattle. Solar distillation, crushed bone or bone char can be used to remove the fluorides from the small quantity of water to be consumed by growing children. Alternatively this small quantity of water could be obtained from another source such as by collecting rainwater off roofs. Drinking and cooking with the high fluoride content water for short periods during the dry season or during a drought could still be considered if rainwater was normally used for this purpose.

Like fluorides, nitrates occur in groundwater due to natural formations. However, unlike fluorides, they also occur from the use of nitrogenous fertilizers by farmers, the gathering of livestock in kraals or around feeding and watering points, pollution from sanitation systems and other forms of effluent, sludge and waste disposal. Thus nitrate levels in groundwater are generally on the increase because of human activities. On the other hand it is important to have an understanding of our present knowledge about nitrate health risks. For non-breastfed infants up to the age of 3 months there is a real danger that nitrogen levels above 20 mg N/ℓ will convert the haemoglobin which ensures that our blood carries oxygen around our bodies into fatal concentrations of methaemoglobin. Once the concentration of methaemoglobin in the blood exceeds 5%, the first symptoms of "blue baby syndrome" or "cyanosis" are generally noticeable, whilst death results at a level of 50% and higher (Terblanche, 1991, quoted in Tredoux, 1993, p. 4). Levels above about 110 mg N/ℓ can be fatal to cattle or cause them to have miscarriages. High nitrate levels have also been named as a possible cause of human birth defects but detailed investigation has provided no evidence of this being so (WHO, 1995, quoted in Tredoux, 1993, pp. 7-8). Attempts have also been made to link other serious health complaints in adult human beings with high nitrate levels in drinking water, but reading the evidence and the comments reported by Tredoux (1993, pp. 4-8) these links appear to be very weak. For example, adults on a farm near Otjiwarongo in Namibia continued to drink water with 268 mg N/ℓ, even after stock losses had occurred on their farm, with no apparent ill-effects (Tredoux, 1993, p. 6).

Solar distillation can be used effectively to remove the nitrates from the small quantity of water to be consumed by infants. Algal ponds and certain bacteria can be used to remove nitrates from larger volumes of water for animal watering, but these methods are not very suitable for domestic water supplies as the treatment residues are difficult to remove and humans find these residues unpleasant. With respect to microbiological denitrification a farmer in the Springbok Flats area is reported to have used molasses as a carbon substrate (Anonymous, 1985, quoted in Tredoux, 1993, p. 9).

Large sums of money are already being spent on upgrading community water supplies to ensure nitrogen levels of less than 10 mg N/ℓ. The fear of nitrate pollution caused by on-site sanitation is also probably exaggerated. Thus there is a real need to monitor the water and the people living in areas vulnerable to high nitrate levels to establish a better understanding of the health risks associated with different nitrate levels and of how such pollution occurs. The knowledge of how the pollution occurs should then be used to find ways in which to prevent or lessen it cost-effectively. However, by far the greatest efforts need to be focused on improving the nutritional levels of the poor, their health and hygiene education, and their access to reliable and bacteriologically safe water that they are prepared to use. Only then will South Africa reduce its unacceptably high mortality rate of 53 deaths of infants under 1 year old per 1000 live births (MOP, 1995, p. 6).

2.3.3 Bad taste, colour or smell: hydrogen sulphide, manganese and iron

Even when groundwater is perfectly healthy to use, it may have a bad taste, colour or smell and/or contain significant concentrations of hydrogen sulphide, manganese or iron which make its use unacceptable to communities. As well as killing harmful bacteria, chlorine in the forms described in 2.3.1 can often be used as an oxidizing agent to remove these unpleasant characteristics and thus make the groundwater acceptable again for community use. If high levels of manganese are to be removed or if chlorination is not effective, potassium permanganate can be used in the same way as non-perfumed bleaches to oxidise the water, but it must be remembered that potassium permanganate is not an efficient disinfecting agent for killing harmful bacteria. A further way of removing iron caused by natural geological formations is illustrated in WRC, 1993 (p. 95). It uses a tray of charcoal chips followed by a tray of granite and a 200 ℓ drum filled with layers of fixed but different size gravel to aerate the water and to precipitate out the iron.

2.3.4 Preventable bad taste and colour: zinc and iron contamination caused by corrosiveness

When existing handpump installations are visited and high iron values are found it is relatively easy to check if the problem is caused by corrosion or the aquifer itself, even if the original quality of the water is unknown (Haldorsen, 1989, pp. 114-117). First thing in the morning after the pump has been unused overnight, take a few samples from the first 50 ℓ of water pumped and check them for iron content. After between 200 and 500 ℓ have been pumped, take a few more samples and check them in the same manner. If the iron content of the second set of samples is significantly lower than in the first set the cause of the problem is corrosion. A similar test for the zinc content on a new handpump-equipped well with the casing, pump rising main and, perhaps, pump rods made of galvanised iron can be used as an early warning test for future problems. Whilst communities are likely to reject water with iron levels of above 1,5 mg/ℓ they are also likely to reject water with zinc contents above 4 mg/ℓ. Therefore, as well as being an early warning test for future problems, the zinc content test may reveal why a community has started to abandon a well soon after commissioning, despite its original acceptance.

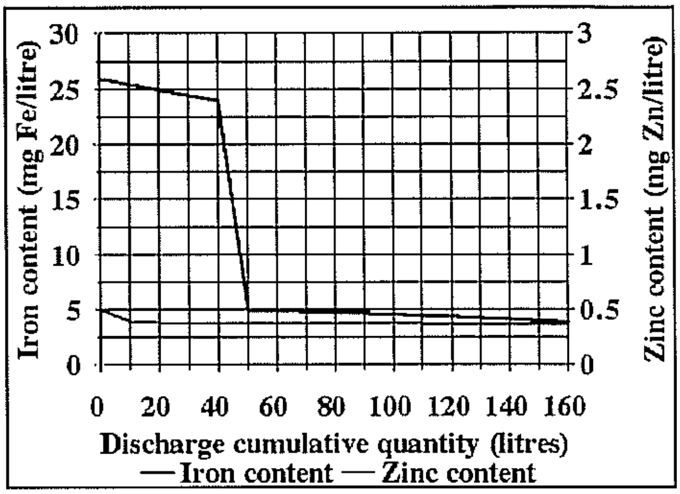


Figure 2.8: Five-year-old well equipped with galvanised iron components (Haldorsen, 1989, p. 115)

Examples after Haldorsen (1989) of variations in iron and zinc concentrations because of materials selection and corrosion and the improvements achieved by changing to corrosion-resistant materials are shown in Figures 2.8 to 2.10.

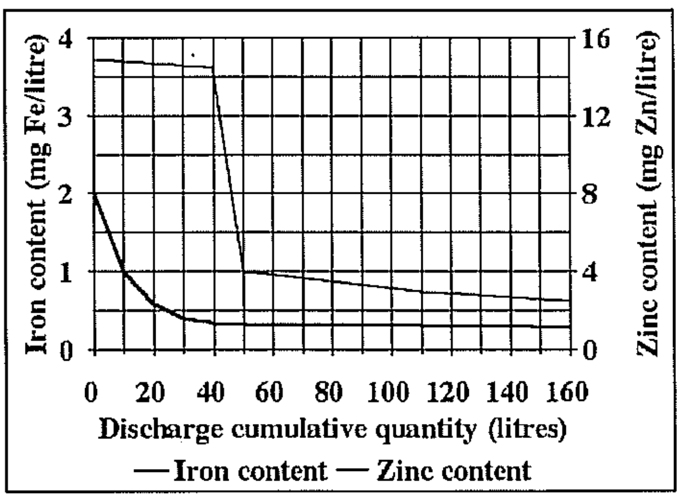


Figure 2.9: New well equipped with galvanised iron components (Haldorsen, 1989, p. 116)

Figure 2.8 shows the iron and zinc content in a five-year-old well with aggressive water which has been equipped with galvanised-iron components. The high and decreasing iron content during flushing of the pump and well, combined with the low but gradually decreasing zinc content, indicates corrosion with most of the "protecting" galvanisation having dissolved, leaving the iron directly exposed to the water.

Figure 2.9 shows the iron and zinc content in a similarly equipped new well with aggressive water. The high and decreasing zinc content during flushing of the pump and well, combined with the relatively low but decreasing iron content, indicates corrosion with most of the "protecting" galvanisation still intact.

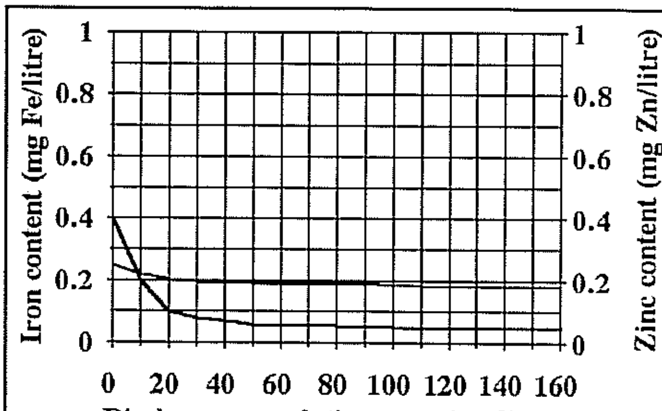


Figure 2.10: Old well equipped with non-corrosive components (Haldorsen, 1989, p. 116)

Figure 2.10 shows a five-year-old well with equally aggressive water but this time the well has only been fitted with uPVC and stainless steel components. Both the iron and zinc content of the water are consistently low. Rehabilitating the first two holes would quickly result in water of equally good quality.

2.3.5 Bad taste and hardness: dissolved salts and other solids

Deep groundwater in valleys and plains can contain high levels of salts and other dissolved solids. The former causes people to complain about the salty brackish taste and the latter results in an excessive consumption of soap. The high levels of salt and other dissolved solids are often caused by the water being old and having been in contact with the confining geological formations for a long time. Seeking water at higher altitudes often locates younger fresher waters but usually at reduced assured long-term yields. Small quantities of such water can be purified using solar distillation but purifying larger volumes requires costly high-tech plant.

2.3.6 Water storage

Very often the groundwater delivered by handpumps is of good quality, free of organic matter and safe to drink, but becomes contaminated during storage. This indicates that the water has been collected, stored or used in an unhygienic manner. Groundwater should be collected in clean containers, and kept covered at all times to prevent insects, small animals, dust, and other airborne pollution from contaminating it. Under such conditions, storing the water, particularly for periods in excess of 24 hours, becomes a treatment process in itself by reducing bacteria and viruses as well as allowing non-dissolved inorganic solids such as sand to settle to the bottom. (Fluorides, nitrates and other dissolved solids are not reduced by storing the water.) Lastly such water must be scooped out with a clean utensil or tipped out, to prevent contamination during use. Taking care in collecting, storing and using the groundwater delivered by handpumps thus truly helps to make them an effective means of providing domestic water supplies.

2.4 Management and social issues

VLOM concepts will always reduce the maintenance costs of handpump installations through reducing the need for transporting heavy maintenance equipment and the time needed for carrying out practically all maintenance tasks. The greatest savings and the most effective maintenance are however achieved through combining the use of VLOM handpumps with the successful introduction of village level management and caretaking of the installation together with the adequate training of local private enterprise area mechanics.

"Local authorities as well as the users still underestimate the importance of maintenance" (Besselink, 1992, p. 3). "There is a great difference between the real and the apparent maintenance costs of handpump systems. Most reports only give a rough and concealing indication. Generally the maintenance of the borehole exceeds the financial capacity of the villagers" (Besselink, 1992, p. 25).

"There are also programmes, such as the handpump-well programme in Burkina Faso, where the community not only pays for and executes all community-level maintenance but also sets aside reserves for the replacement or extension of the village water supply" (van Wilgenburg 1991, pp. 20-21). (Sadly Wisner, 1988, pp. 155-156, reports that in this same country the estimated percentage of malnourished children is the highest in the world.) In their handpump manual, Arlosoroff *et al.* (1987, p. 4) state that they are seeking additional evidence of "practical community-level cost recovery and management mechanisms". It is interesting to note that a follow-up volume published five years later only discusses handpump technology (Reynolds, 1992).

"In general, direct involvement of the government in the maintenance of pumps proves to be unsuccessful. Furthermore, the costs of functioning are excessive. The best is to use an area mechanic. The contribution of a village mechanic is undesirable for most deep-well handpumps. An area mechanic is better trained and has more experience and tools. The contribution of the local authority is limited to initiator and controller to prevent forcing-up of prices and mediator in a global sense in conflicts between villagers, mechanics and the spares distributer" (Besselink, 1992, p. 25).

How many area mechanics are required? "In Burkina Faso, at the provincial level, enough area mechanics were trained to service the pumps on the basis of one mechanic to every ten pumps" (Arlosoroff *et al.*, 1987, p. 33). The same source states that in India area mechanics have responsibility for maintaining "50-60 pumps" (p. 34).

2.5 Recommendations abstracted from the literature

In the majority of environments **all** the following conditions need to be complied with for the achievement of effective community water supplies using deep or shallow well handpumps:-

- There should be full community participation in the project from the feasibility study stage, carried out within a framework which ensures community control of all phases of the project and results in the community accepting ownership on completion of construction (IRC, 1988, p. 52).

- The basic concepts should be well thought through at the feasibility study stage. Within what distance from the village must water be found for handpumps to be acceptable to the community? Taking water depth into consideration, how many pumps will be required by the community to supply their needs adequately? Although handpumps can be an acceptable choice for many domestic and livestock water supply requirements, since any individual user will only operate the pump for a few minutes per day, they are unlikely to be suitable for community gardens and irrigation. Because of the greater volumes of water required and because humans have a low work capability (250 watts per day) and a low overall efficiency in converting food energy to mechanical energy (7 to 11%), human-powered pumps shouldn't even be considered for heads much above 8 m. However, if human-powered pumps are to be used, for applications up to 8 or 10 m, a foot-operated bicycle-type drive is usually the best choice (Fraenkel, 1986, pp. 133-137).

- Proper borehole development is important to ensure good alignment, a sustainable yield and a relatively sand-free yield (IRC, 1988, p. 85-87). Wells must be drilled deep enough and pump cylinders installed low enough to ensure water is available throughout the year (IRC, 1988, p. 34).

- Water quality should be checked for health, taste and corrosion criteria.

- Standardisation around a limited number of pumps should be implemented to make maintenance, the planning of maintenance and the organisation of spare parts for maintenance easier (Kjellerup and Ockelford, 1993).

- Choosing the correct criteria for the selection of the standardised range of handpumps is also important. Thirteen technical criteria have been selected from the literature which must be considered when selecting handpumps (Appendix A). The criterion of price must be added to this list.

- Cost recovery is an essential aspect of sustainable implementation and thus there must be a community structure capable of organising and implementing cost recovery as well as organising the pump caretaker and maintenance support discussed below. (People value something that they have to pay for more than free goods, and ownership can only be transferred to a community when the community accepts a central role in paying the operation and maintenance costs.) The literature is, however, inconsistent with respect to estimating actual operation and maintenance costs and the ability of different communities to pay for these costs in full (Evans, 1992, p.4).

- Specific resident community members should be appointed as pump caretakers and should be trained to carry out their duties competently. A typical caretaker's duties are as follows: promoting hygienic conditions around the handpump installation, monitoring the pump's performance, carrying out routine preventive maintenance including the replacement of minor above-ground components and initiating the implementation of maintenance tasks outside his or her own competence (Pacey, 1980, pp. 28-29).

- For pumping heads in excess of about 12 metres, irrespective of the pump chosen, there will be maintenance tasks beyond the capabilities of the community caretaker, who will then need technical back-up and spares from outside the village. Generally the literature discourages direct government involvement in such maintenance work and describes such involvement as ineffective and costly. It rather favours the training of area mechanics, with government's role being limited to ensuring that the mechanic's pricing structure is fair and acting as mediator in conflicts between villagers, mechanics and the spares distributer. However, there is consensus that the initiative for arranging such support should come from within the community and that payment for services and/or materials should at least be managed by the community (Arlosoroff *et al.*, 1987, pp. 3-4).

- Whilst the improvement in the quality of life achieved by a community which has a reliable supply of good quality water close at hand must not be under-estimated, the benefits will be greatly enhanced by including a participatory hygiene education programme as an integral part of any domestic water supply project (Black, 1990, pp. 100 and 114-116).

3 ANALYSIS OF SOUTH AFRICAN HANDPUMP INSTALLATION AND GROUNDWATER RECORDS

3.1 Introduction

Handpump installation and groundwater records were analysed to judge to what extent the different conclusions drawn from the literature survey apply in South Africa. For example, when developing a well in South Africa and buying a pump to install in it, must the corrosiveness of the water be taken into account? The records and procedures used in the analysis are detailed in each of the sections that follow. Factors examined include groundwater levels and corrosiveness, borehole yields and recovery rates, and handpump maintenance.

3.2 Importance of handpump installations with respect to community water supplies

Whilst the surveys of local handpump manufacturers and handpump purchasers were being carried out, efforts were made to find out the size of the South African handpump market. However, handpump manufacturers would not disclose their sales figures. In addition, the number of significant handpump purchasers in South Africa could not be established. Therefore assessing the size of the market from the answers given by purchasers with respect to how many handpumps they had purchased in the previous twelve months was also not possible.

Table 3.1: 1995 borehole records of ex-Lebowa and -Venda areas of Northern Province

Description	Number	%
Village details:		
Number of villages with registered boreholes	1544	
Number of villages with some pump details recorded	**1058**	**100**
Number of villages with handpumps recorded	676	64
Number of villages with only handpumps recorded	332	31
Number of villages with only one pump recorded and with that one pump being a handpump	163	15
Borehole details:		
Total number of boreholes registered	**4123**	**100**
Number of boreholes recorded as being dry when last monitored	189	4,6
Number of boreholes recorded as having no pump fitted when last monitored	67	1,6
Number of boreholes further analysed below	**3867**	**93,8**
Pump details:		
Number of recorded handpumps fitted	1520	54
Number of recorded engine powered pumps fitted	849	30
Number of recorded grid electricity motor powered driven pumps fitted	137	5
Number of recorded windmill powered pumps fitted	294	11
Number of recorded solar energy powered pumps fitted	1	0
Sub-total	**2801**	**100**
Number of registered boreholes with no pump information equipment details	1066	
Total	**3867**	

A colleague at the CSIR had however obtained copies of the records related to boreholes situated in the ex-Lebowa and -Venda areas of Northern Province (Schoeman, 1996) and transferred them onto a single spreadsheet. Table 3.1 summarises the data recorded in that spreadsheet and Figure 3.1 illustrates graphically that handpumps comprise over half the total number of known borehole pumps in these two areas.

The first thing to note from Figure 3.1 is that over 50% of all the **known** borehole pumps installed in the areas examined are handpumps. Actual numbers for the whole of Northern Province are probably in excess of 2 000. Just over 20% of the rural population of South Africa live in Northern Province (May *et al.*, 1995). A higher percentage of the rural population in both KwaZulu-Natal and the Eastern Cape is served by handpumps, as are a significant number of communities in the less subsistence-based rural provinces of North West, Mpumalanga and the Free State. It is therefore safe to estimate that there are at least 10 000 handpumps installed in South Africa. If we assume that 200 people are primarily dependent on each of these handpumps, 2 million people or 10% of the South African population are primarily dependent on handpumps for their water supply.

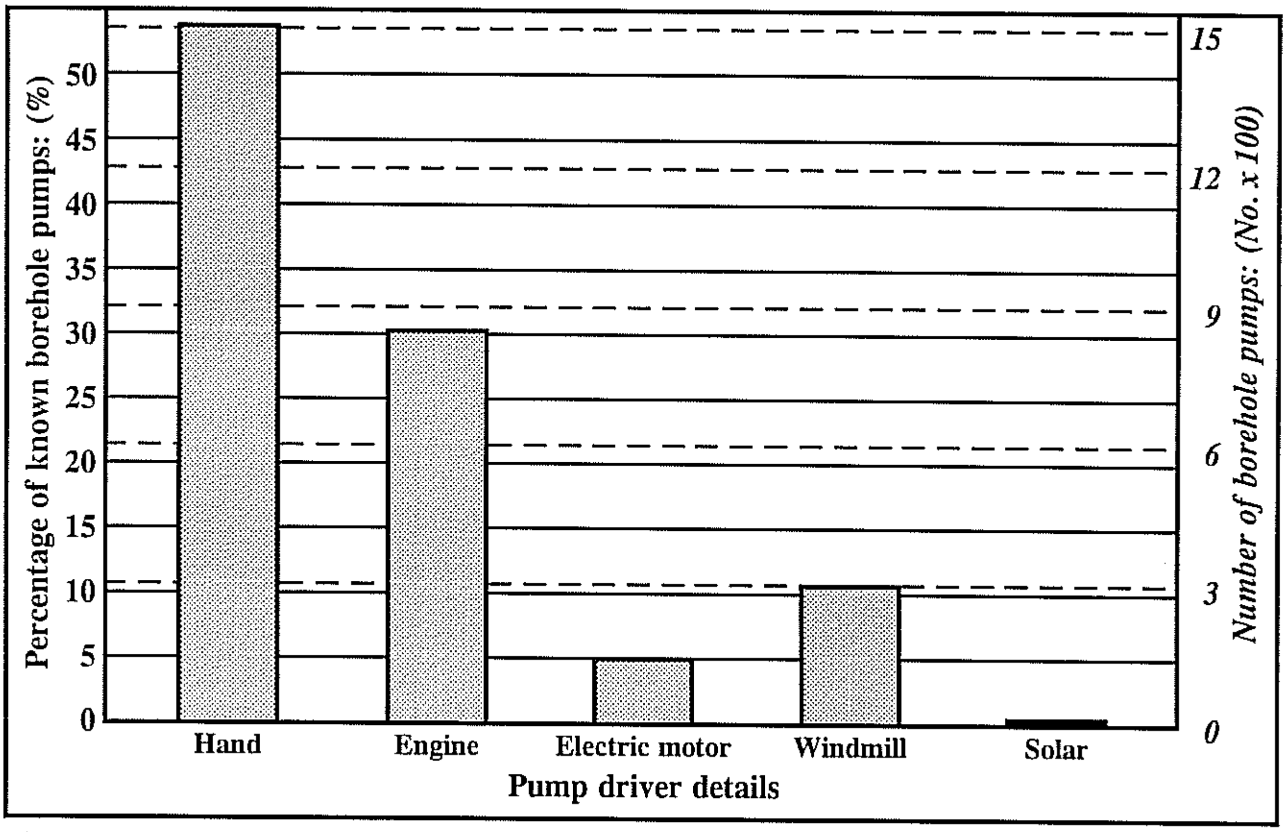


Figure 3.1: Numbers of known borehole pumps in the ex-Lebowa and -Venda areas of Northern Province

The total cost of drilling a well, developing it and installing a handpump is about R 40 000 per handpump, including VAT. Thus these handpumps represent an investment of about R 400 million. They are mostly installed where spring protection or simple gravity surface-abstraction schemes are not practical. Thus besides animal-, windmill- and solar-powered borehole pumps, possible alternative ways of serving these communities are with engine- or motor-driven borehole pump schemes or with treated and pumped surface water schemes. Serving these same isolated communities with engine- or motor-driven pumps and with RDP-level reticulation would require double the investment, assuming there was sufficient groundwater available in the immediate vicinity. The operation and maintenance costs of such schemes are approximately three times the operation and maintenance costs of handpump schemes. Pumped surface-water schemes, with relatively short bulk-delivery pipelines of between 3 and 5 km, are likely to require a capital investment of 3 to 4 times that required for the handpump option and have operation and maintenance costs, after treating the water, in excess of that experienced for schemes with engine-and motor-driven borehole pumps (costs abstracted from Hazelton and Masango, 1994). In short therefore, excluding the convenience and health hardships caused by the handpump water supply schemes not working effectively, the current investment and its alternatives make raising the reliability and effectiveness of the existing handpump schemes worthy of serious attention.

3.3 Groundwater static depths

Through reference to the Department of Water Affairs and Forestry National Groundwater Database (DWAF, 1994), static water levels in a representative sample of 476 boreholes from throughout South Africa were analysed to examine the distribution. The results are shown graphically in Figure 3.2 and are analysed in terms of application below:

0 - 10 m = 30% = low-lift application
10 - 20 m = 30% = intermediate-lift application
20 - 35 m = 22% = high-lift application
35 - 65 m = 12% = extra-high-lift application
>65 m = 6% = not suitable for handpump application

In practice these ranges are not clearly defined. Changes in the static water table level caused by seasonal weather changes and drought conditions can change a low-lift application into an intermediate-lift application or a medium-lift application into a high-lift application. Hence the conservative definition of the ranges compared with World Bank definitions, which are as follows: low lift 0 - 12 m, intermediate lift 12 - 25 m and high lift 25 - 45 m . The World Bank does not specify a range for extra high lift but there are a few handpumps which their manufacturers claim have been designed to operate at depths down to 80 and 100 m . At depths in excess of 60 m the human effort required to pump any water becomes excessive. Thus the range 60 to 80 m can be regarded as the boundary region with respect to the usefulness of handpumps.

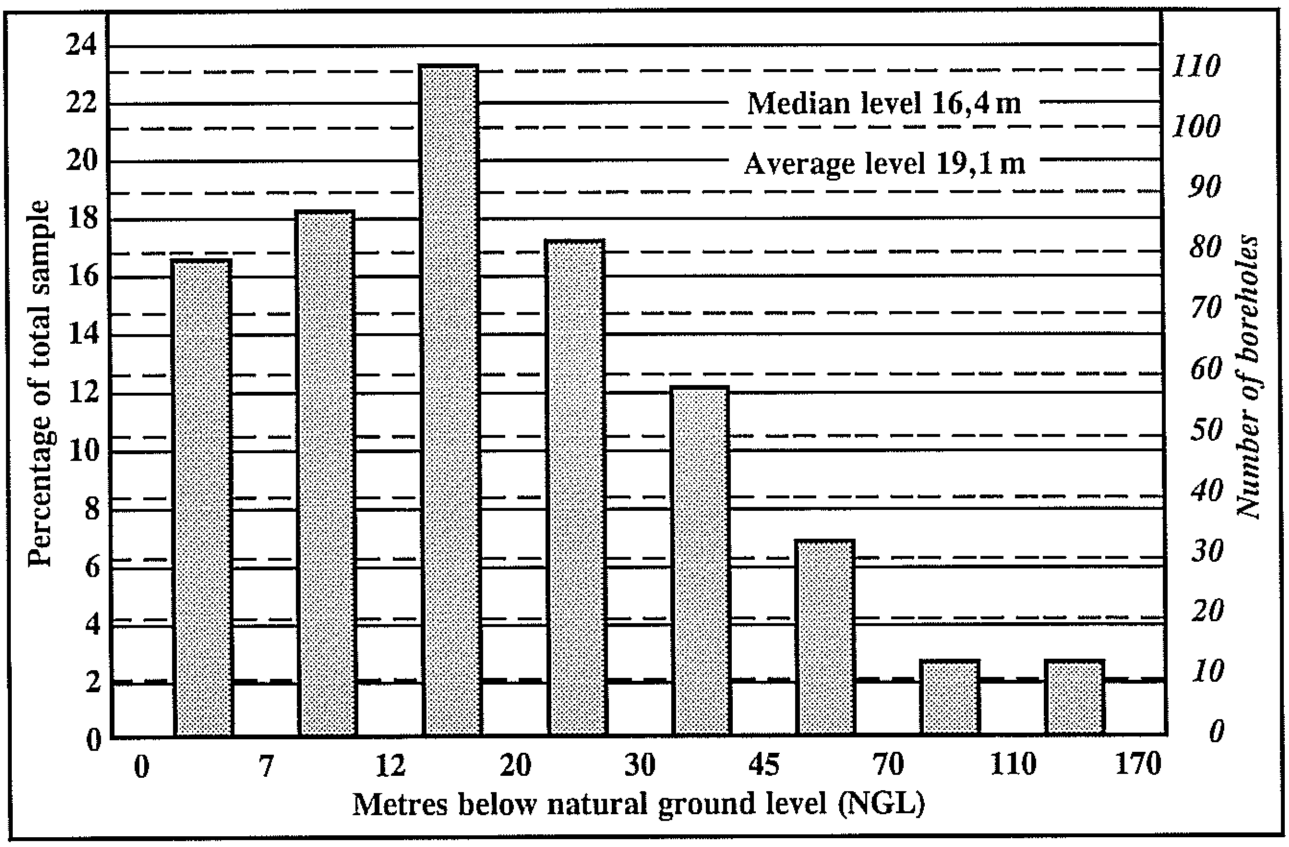


Figure 3.2: Range of static water levels found in a sample of 476 boreholes

Further analysis, as reported in the next two sections, however, indicates that water being abstracted by nearby engine- or motor-driven pumps and the low yield of many of the boreholes on which handpumps are fitted can change application categories even more dramatically than the seasonal and drought changes reported above.

3.4 Changes in groundwater static depths with time

Common wisdom states that handpumps have a negligible long-term effect on groundwater depths. Whilst this statement is generally true it can be very misleading, since this does not mean that boreholes fitted with handpumps never dry up or that the water level never drops significantly whilst pumping is taking place (refer Section 3.5.2). However, this section only reports on static water table depth changes.

With the strong yearly seasonal rainfall variations and drought patterns in South Africa, one would expect to find noticeable variations in the groundwater static depths with the seasons and longer term drought patterns. However, such variations are not apparent from visually examining the 172 long-term borehole records available in South Africa and reported on later below. It thus appears that in most areas of South Africa such variations are not significant. (For more information on possible correlations between water table depths and rainfall refer DWAF, 1995a.)

However some boreholes are fed from local sills. Due to the natural hydrogeological cycle, such boreholes can dry up completely during the dry season or during periods of drought, with little or no water abstraction taking place.

Another problem is variations in water levels caused by water being abstracted by engine- and motor-driven pumping plant in neighbouring areas. For example, Simon Forster, who was coordinating the Department of Water Affairs and Forestry's 1992/93 drought relief programme in the ex-TBVC and self-governing areas of South Africa, has reported that during that drought groundwater levels in parts of the Northern Province fell in excess of 10 m in some villages where only handpumps were installed. Local people and geohydrologists suspect that the use of groundwater for irrigation on nearby white farms was to blame (Forster, 1994, p. 36). In future, therefore, water levels in boreholes fitted with handpumps may also become more vulnerable to the abstraction of water by engine- and motor-driven pumping plant in neighbouring villages.

Because of the lack of borehole water level monitoring in community water supply schemes, the extent of such problems is generally unknown.

However, by referring to the Department of Water Affairs and Forestry National Groundwater Database (DWAF, 1995b) we were able to look at what is happening in the 172 boreholes from throughout South Africa for which some records exist over a 10-year period. (Note: Of the hundreds of thousands of boreholes drilled in South Africa, the National Groundwater Database only contains records on changing water table depths for approximately 2 500 boreholes, and of these, only a small number, 172, have records covering 10 years or more.) Figure 3.3 shows graphically what has been happening in 6 of these boreholes from around the country. These 6 boreholes give some indication of what can happen to the groundwater table when the water is mined in a manner which ignores that it is a finite resource. The sample is not representative as the boreholes have been purposely chosen to show examples of falling water table levels from around the country. A sample of 3 boreholes with the levels rising in a similar manner could have been chosen. However, the overall trend from the 170 boreholes depicts a falling water table level.

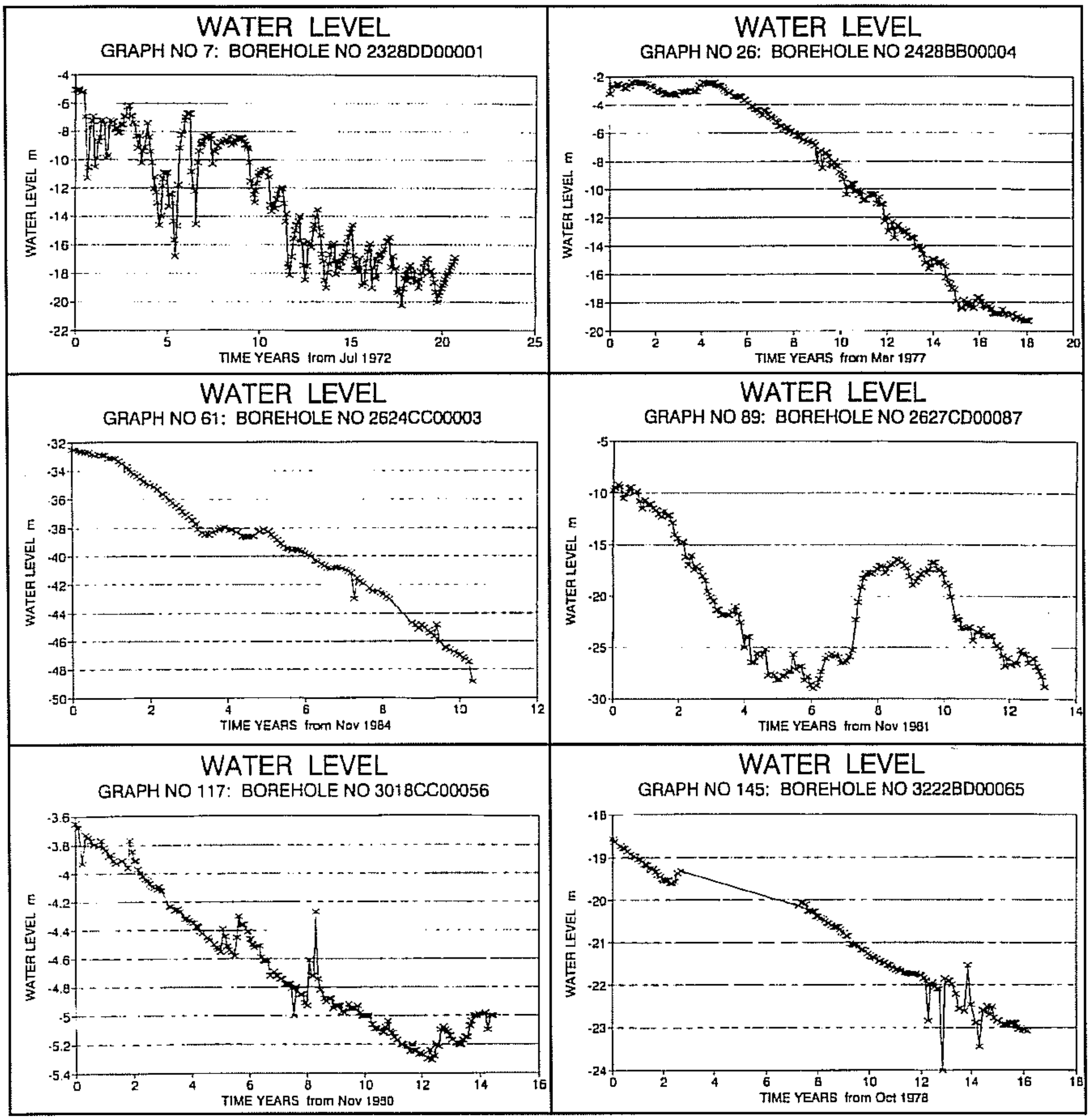


Figure 3.3: Examples of falling groundwater levels from around South Africa

3.5 Borehole yields and recovery rates

3.5.1 Borehole yields

From the Department of Water Affairs and Forestry National Groundwater Database (DWAF 1994), a representative sample of 1 525 boreholes from throughout South Africa which had information on yields were selected. Table 3.2 is a summary of the data abstracted. The majority of handpumps in South Africa are installed on boreholes with yields of up to 60 ℓ/min, because for boreholes above that rate, authorities generally make use of the additional yield by installing engine- or motor-driven pumps. It is also assumed that boreholes with yields of less than 2 ℓ/min are not equipped with any sort of pump. Figure 3.4

illustrates graphically the spread of yields of those boreholes on which the majority of handpumps are fitted in South Africa.

Table 3.2: Nationwide sample of South African borehole yields abstracted from the National Groundwater Database (DWAF, 1994)

Yield range ℓ/min	Number of boreholes	% in range 2 - 60 ℓ/min	% of all boreholes
<2	75	-	4,9
2 - 6	150	20,1	9,8
>6 - 12	107	14,3	7,0
>12 - 18	96	12,9	6,3
>18 - 24	71	9,5	4,7
>24 - 30	70	9,4	4,6
>30 - 36	51	6,8	3,3
>36 - 42	63	8,4	4,1
>42 - 48	61	8,2	4,0
>48 - 54	35	4,7	2,3
>54 - 60	43	5,8	2,8
Sum range 2 - 60 ℓ/min	**747**	**100,0**	**49,0**
>60	703	-	46,1
Sum all	**1 525**	-	**100,0**

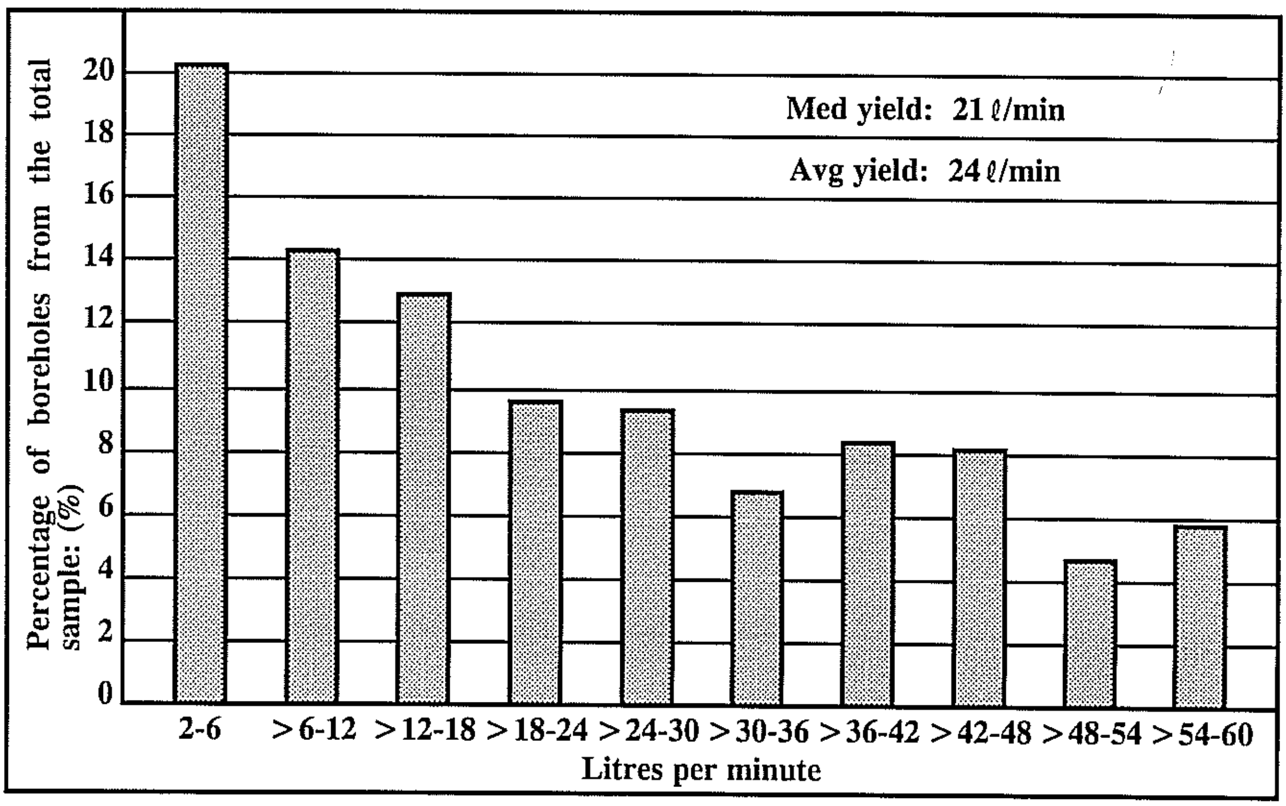


Figure 3.4: Spread of yields of boreholes in South Africa between 2 and 60 ℓ/min

As the National Groundwater Database (DWAF, 1994) rarely records what pumps are fitted to boreholes, it is possible that boreholes with yields higher than 2 ℓ/min are not equipped. If this were the case Figure 3.4 would not be representative of the spread of yields of wells fitted with handpumps. Therefore, to check if the assumptions on which Figure 3.4 were plotted are reasonable, reference was made once again to the borehole records of the ex-Lebowa and -Venda areas of South Africa (Schoeman, 1996). In this way it was confirmed that in these areas at least very few boreholes with yields in excess of 60 ℓ/min were equipped with handpumps, whilst some with yields as low as 1 ℓ/min were so fitted. Figure 3.5 is a plot of all the known yields of 867 boreholes equipped with handpumps, excluding the few above 60 ℓ/min. Some additional adjustments were made to remove distortions caused by some records being rounded-off to the nearest 5 ℓ/min. The general shape of Figures 3.4 and 3.5 are remarkably similar, as are the median and average yield figures. Thus the initial assumption that boreholes with very low yields are fitted with handpumps is at least true of the ex-Lebowa and -Venda areas of South Africa and is likely to be true in other areas.

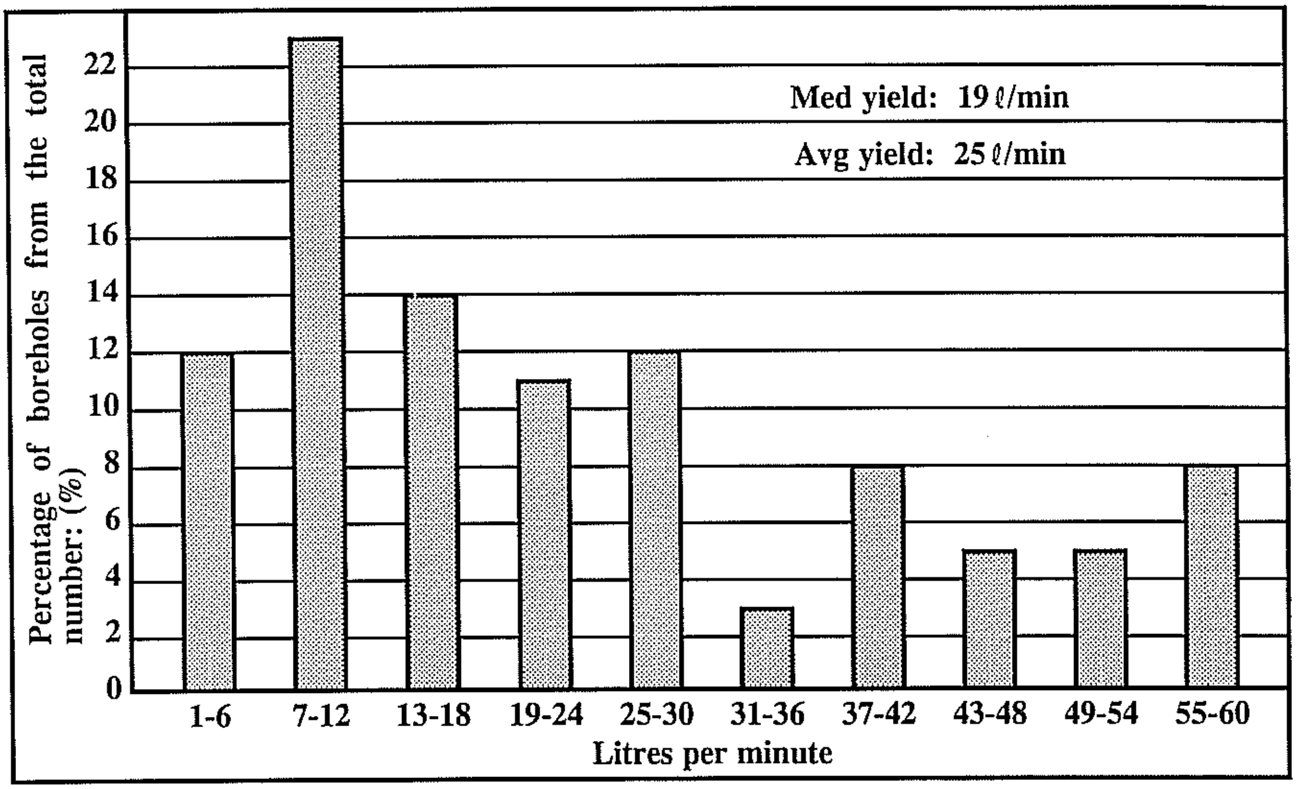


Figure 3.5: Spread of yields of boreholes between 1 and 60 ℓ/min fitted with handpumps from records of the ex-Lebowa and -Venda areas of Northern Province

3.5.2 Borehole recovery rates

Tests are normally carried out to establish the safe long-term yield of a borehole with respect to its aquifer. As commented on in Section 3.4, handpumps generally have a negligible long-term effect on groundwater levels because of their low pumping rate and because, on average, they are only used about 5 hours each day. Thus, on their own, the above tests indicating low yields only give a vague warning that it may not be possible to pump at the desired rate from the boreholes, but they do not clarify the general suitability of the boreholes for handpump use nor disclose the water level drawdown that is likely to occur whilst pumping is taking place. Figure 3.6 depicts the results of a simulated short-duration constant pumping rate and recovery test on a borehole with a highly variable recovery rate. As drawn, the recovery rate follows the curve: *the water level = k[total recovery time - actual time]^3 + the static water level.*

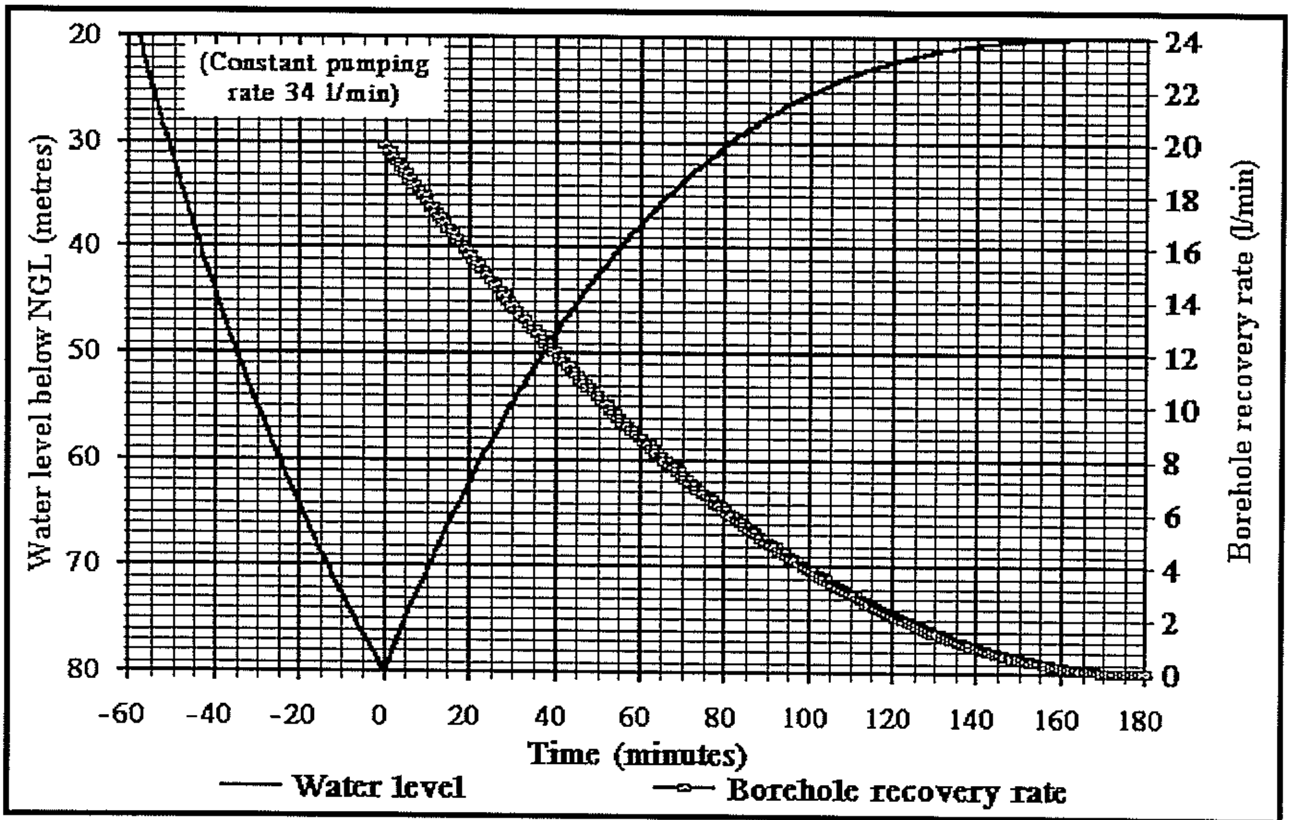


Figure 3.6: Simulated constant pumping rate and recovery borehole test: highly variable recovery rate

The borehole recovery rate was obtained by checking the distance the water rose in the well in measured time intervals and assuming that the effective area of the hole was 0,02 m^2, which corresponds to a well diameter of 160 mm. This recovery rate from Figure 3.6 can be replotted on Figure 3.7 using the water level as the x-axis rather than time. Then, if the characteristic curve of the handpump to be installed on the well is plotted on the same figure, Figure 3.7, one can immediately check the depth at which the pump must be installed to allow pumping to proceed at the maximum rate and also what that rate will be. For this hole, with its highly variable recovery rate, if the pump is installed at 45 m, which may well correspond to its maximum working head, one can pump at a rate of about 10,6 ℓ/min, whereas if it is installed at 25 m, 5 m below the static water level, one is only able to pump at about 3,8 ℓ/min. Despite the greater pumping effort required and the likely higher wear on the handpump, practically all community members would favour the pump being installed at the lower depth so as to have the opportunity of being able to pump water at the substantially higher rate.

(South African manufacturers, purchasers and users all seem to agree that there is no necessity, from a reliability point of view, to match the pump to the available yield. That is, installing the pump in the example just quoted at 25 m and pumping lots of air in addition to the water will not harm the handpump. This appears to be logical since in the case of rotodynamic pumps, allowing air to be pumped with the water does not damage them but rather prolongs their life when this is done to alleviate cavitation. The above comments are, however, contrary to Arlosoroff *et al.* (1987, p. 53), who state that for low-yielding boreholes the pump chosen should have a design discharge reasonably matched with the borehole recovery rate so as to prevent air pumping, and borehole and pump damage. Thus additional monitoring is required to check which statement is more correct.)

However, not all boreholes have such variable recovery rates. Figure 3.8 reflects the results of a simulated constant pumping rate and recovery test for a borehole with only a slightly variable recovery rate. For Figure 3.8 the recovery rate follows the curve: *the water level = k[total recovery time - actual time]*^{1,5} *+ the static water level.*

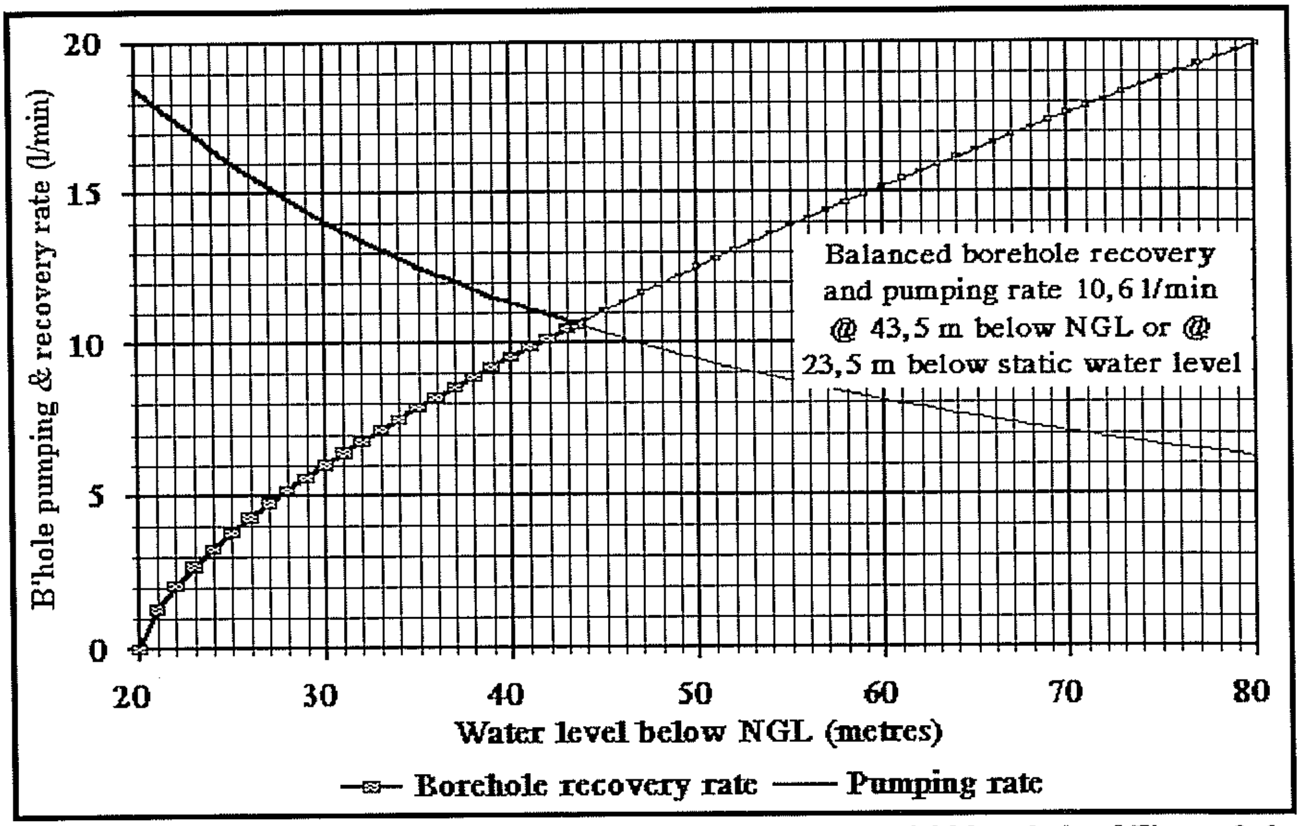


Figure 3.7: Drawdown and balanced pumping rate on the low-yield borehole of Figure 3.6

In the same way as Figure 3.7 is based on Figure 3.6, Figure 3.9 is a replot of the recovery rate for the borehole represented in Figure 3.8. This borehole has a static water level of 5 m and thus at first glance one is likely to recommend a direct action piston pump installed at about 10 m. If such action was taken the pump would deliver water at approximately 4 ℓ/min because of the low yield and variable recovery rate of the borehole, instead of the expected 26 ℓ/min from a good direct action pump with a 10 m lift. Possible pumps for this borehole, assuming the water is non-corrosive, include:

a) A standard extra-high-lift piston pump installed at 60 to 65 m depth. This option would deliver approximately 8,8 ℓ/min.

b) A standard extra-high-lift progressive cavity pump fitted with a 1:2 increasing speed gearbox, also installed at 60 to 65 m depth. Delivery would also be similar, at approximately 8,7 ℓ/min. The progressive cavity pump curve has been drawn lower than the piston pump curve in response to community users' general comment that progressive cavity pumps pump less water than good piston pumps. (In drawing this progressive cavity pump's curve a faster handle speed has been assumed for low heads than for high heads: 60 rpm for 20 m head gradually reducing to 40 rpm for 80 m head. The typical discharge rates versus total lift curves for piston pumps are also drawn assuming the same freedom, with users free to vary the stroke as well as the speed for lever-actuated pumps.)

c) A standard high-lift VLOM piston pump, maximum working head approximately 45 m. This pump should be installed at approximately 40 m so that it cannot be subject to pumping heads in excess of its maximum working head. It will deliver approximately 8,0 ℓ/min plus some air.

As little additional water is delivered by installing an extra-high-lift pump at 60 m, option c) would be recommended for acceptance on the well illustrated in Figures 3.8 and 3.9. If corrosion is a problem it will also be easier and cheaper to source a suitable high-lift VLOM pump, for installation at 40 m, than a suitable extra-high-lift VLOM pump, for installation at 60 m .

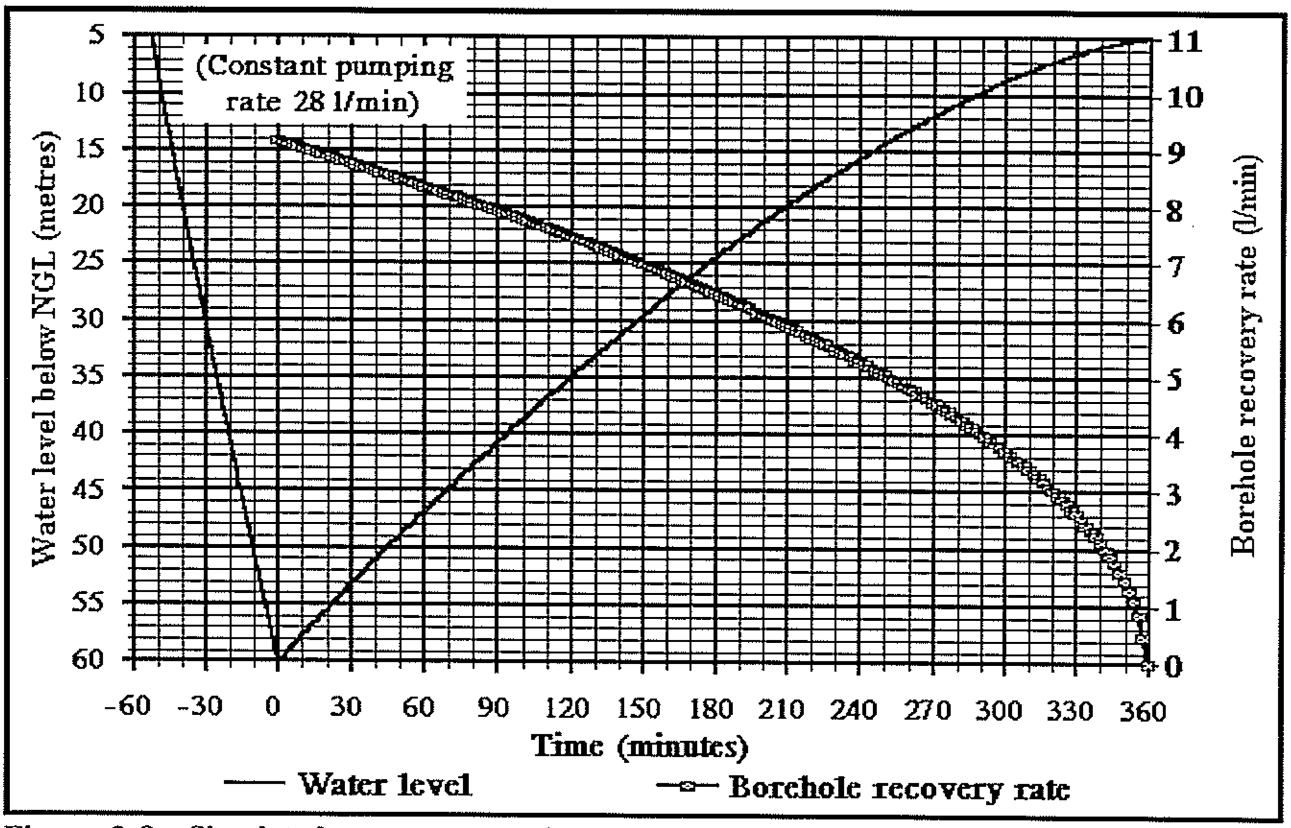


Figure 3.8: Simulated constant pumping rate and recovery borehole test: slightly variable recovery rate

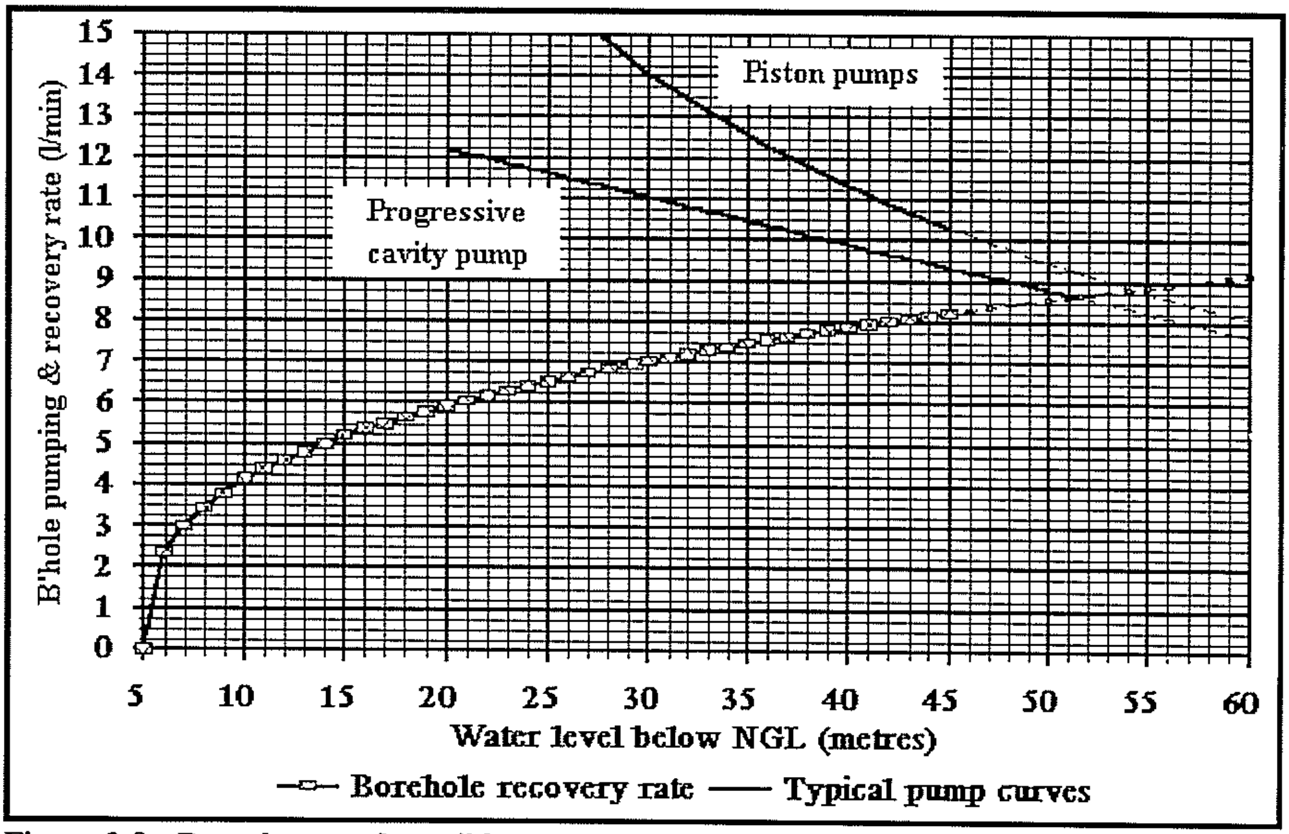


Figure 3.9: Drawdown and possible pump curves for the low-yield borehole of Figure 3.8

Thus, for low-yield boreholes it is essential to know the recovery rates over the full drawdown depth before deciding at what depth to install the pump, what type of pump to select and how many people it can serve effectively. Copies of the results of such tests should be placed in the operating and maintenance booklet for the installation, and in the National Groundwater Database.

3.5.3 Shallow well recovery rates

Other handpumps are installed on shallow wells which receive seepage water through the surrounding sand. In areas where recovery rates are a problem, it is advantageous to dig the well by hand to a diameter of between one and three metres to increase the area available for the water to seep through. Such wells must be lined both to ensure the safety of the diggers and to prevent their collapse in service. This is best done with shallow loose-fitting socket-and-spigot concrete rings.

Deepening a well also increases the available seepage area. It is thus best to dig this type of well at the end of the dry season. In addition, once water is struck, an engine-driven sand pump should be hired to remove all the incoming water and thus allow digging to continue to the required depth.

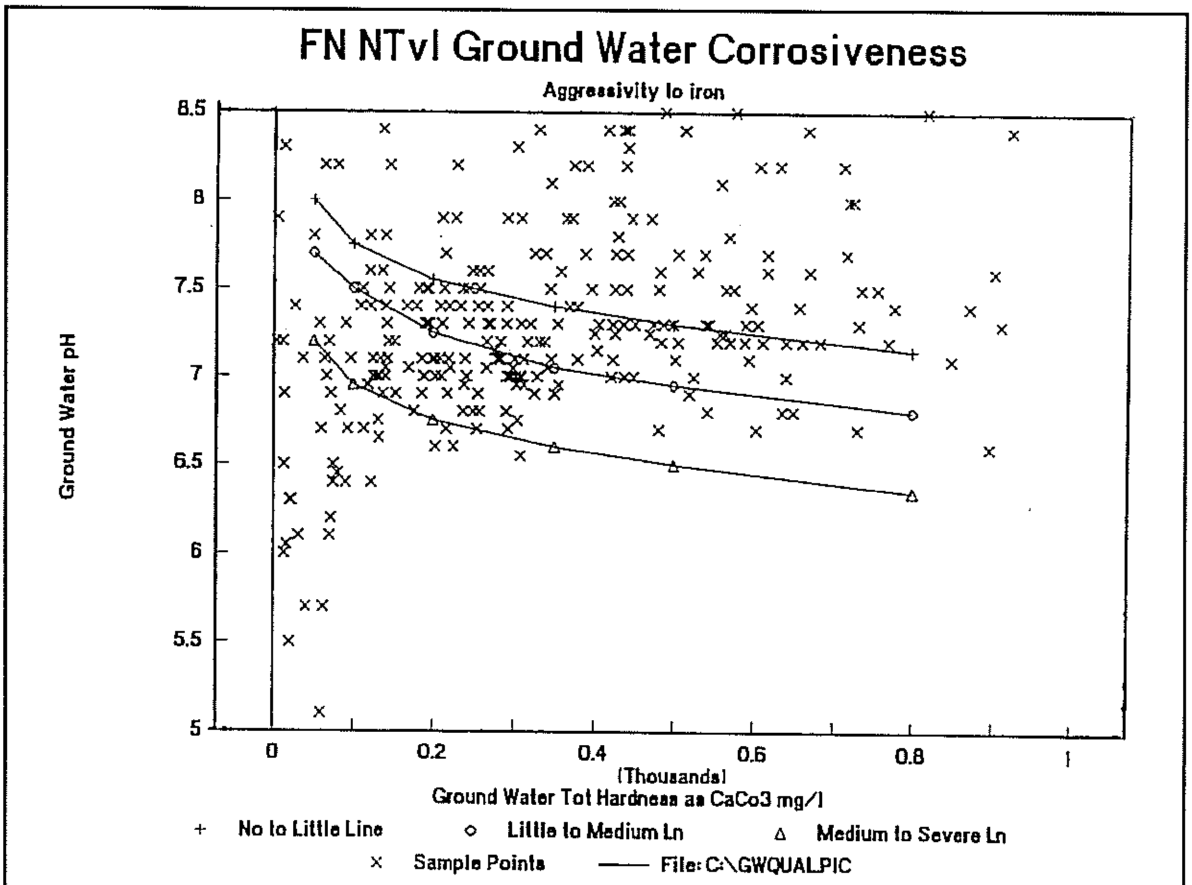
After the well is complete, the top section outside the concrete rings should be sealed before constructing a combined well cover and pump platform over the hole and a fence around it. These items are required to prevent contamination of the water in the well and to provide a hygienic area around it whilst customers are collecting water. The cover over the well should have an access hatch and this hatch, like the pump mounting block, should be raised above the general platform to ensure that water spilt during pumping does not find its way back into the hole.

3.6 Corrosiveness of groundwater

This section reports on the corrosiveness of groundwater in South Africa. The results of tests carried out by the CSIR on a large number of boreholes in various parts of the country between 1985 and 1995 were examined (Prinsloo, 1996). Information on corrosiveness was found in 450 cases. This information was then plotted for five geographical areas by the method recommended by Wollschied (1990). (See Figure 3.10.) The plotted results are summarised in Table 3.3, which indicates that for 15% of the wells corrosion will be severe and as a result galvanised-iron components should never be used in the exploitation of such water. For a further 25% of the wells, the parameters plotted predict moderate corrosion. It appears from the literature that galvanised iron may still be practical for some of these applications but that final recommendations would depend on other factors such as the water's conductivity, or the presence of free oxygen, chlorides, humic acids or hydrogen sulphide.

Table 3.3: Groundwater corrosiveness in various parts of South Africa: aggressiveness to iron

Number of samples Area	Severe	Mod-erate	Little	~None	Total	% Severe	% Mod-erate
Northern Province: far north	34	75	68	84	261	13	29
Northern Province: south and east	22	13	18	38	91	24	14
Northern Province: miscellaneous	4	6	7	14	31	13	19
KwaZulu-Natal	6	13	7	18	44	14	30
Eastern Cape: Ciskei area	0	5	4	14	23	0	22
Sum of all wells sampled	**66**	**112**	**104**	**168**	**450**	**15**	**25**



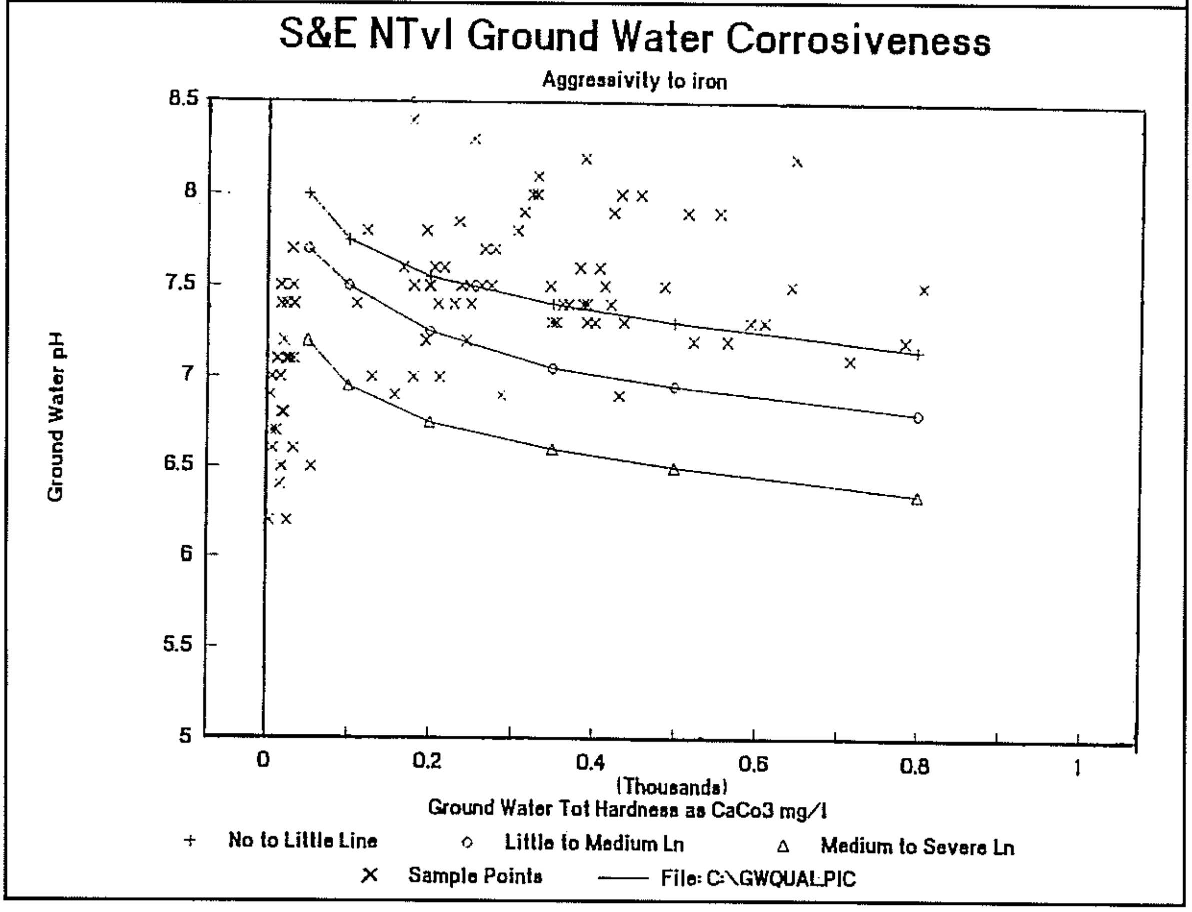
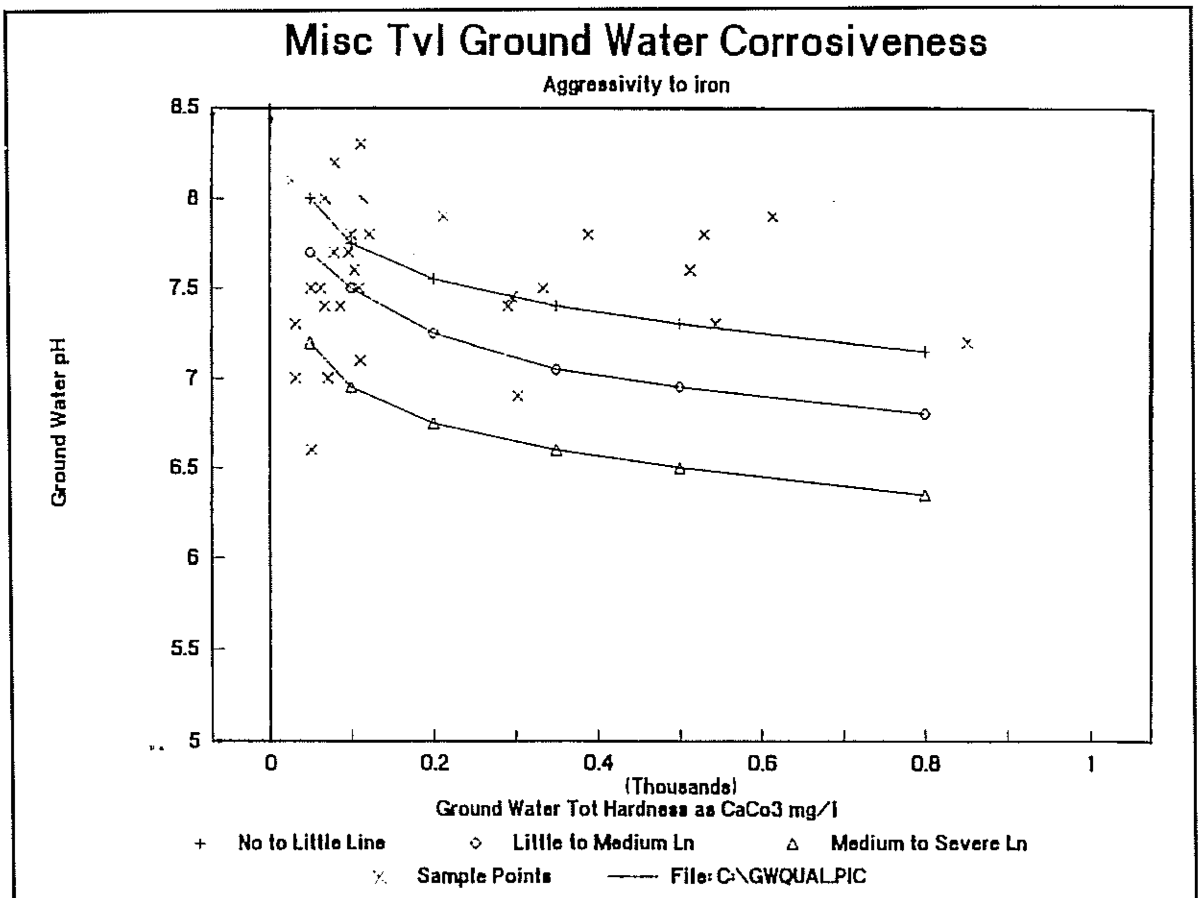


Figure 3.10: Aggressiveness of South African groundwater to iron (cont. overleaf)



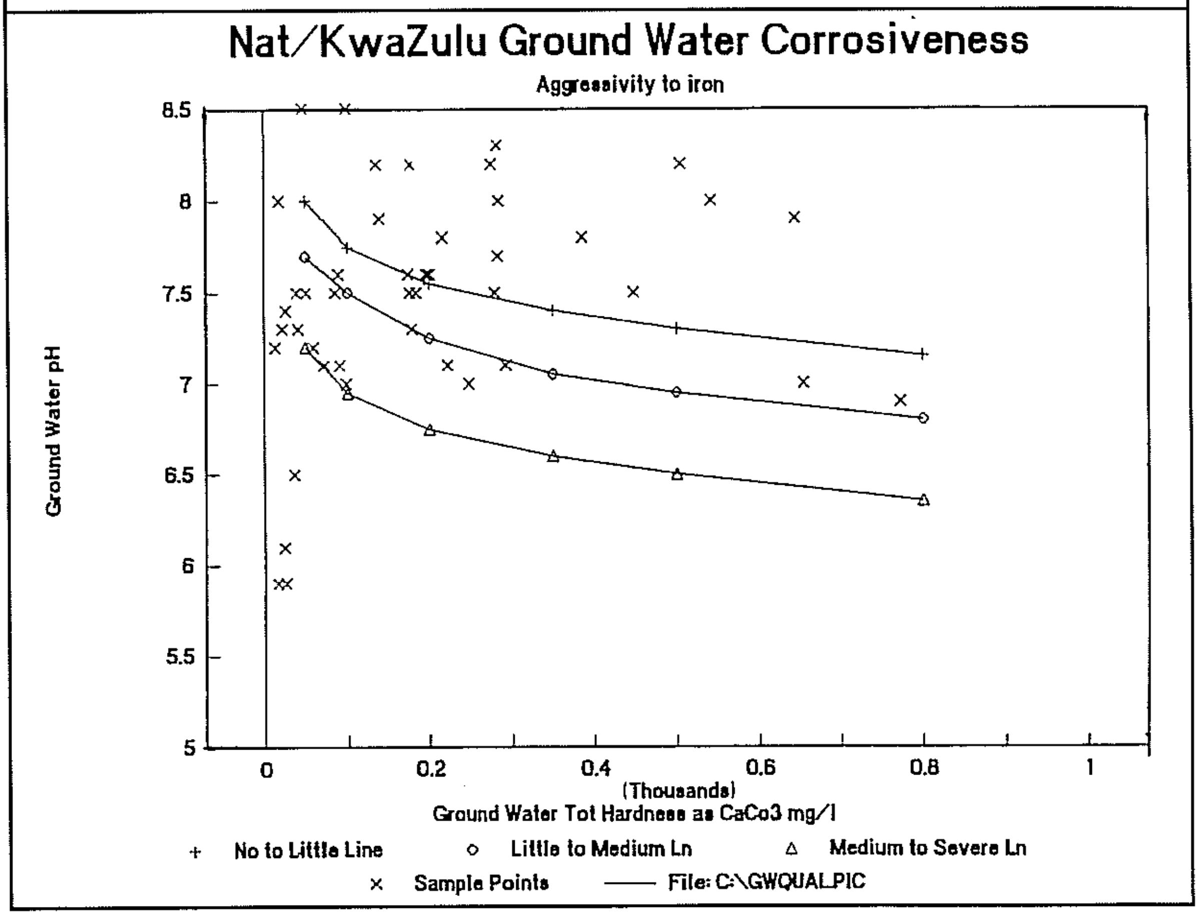


Figure 3.10 cont.: Aggressiveness of South African groundwater to iron (cont. overleaf)

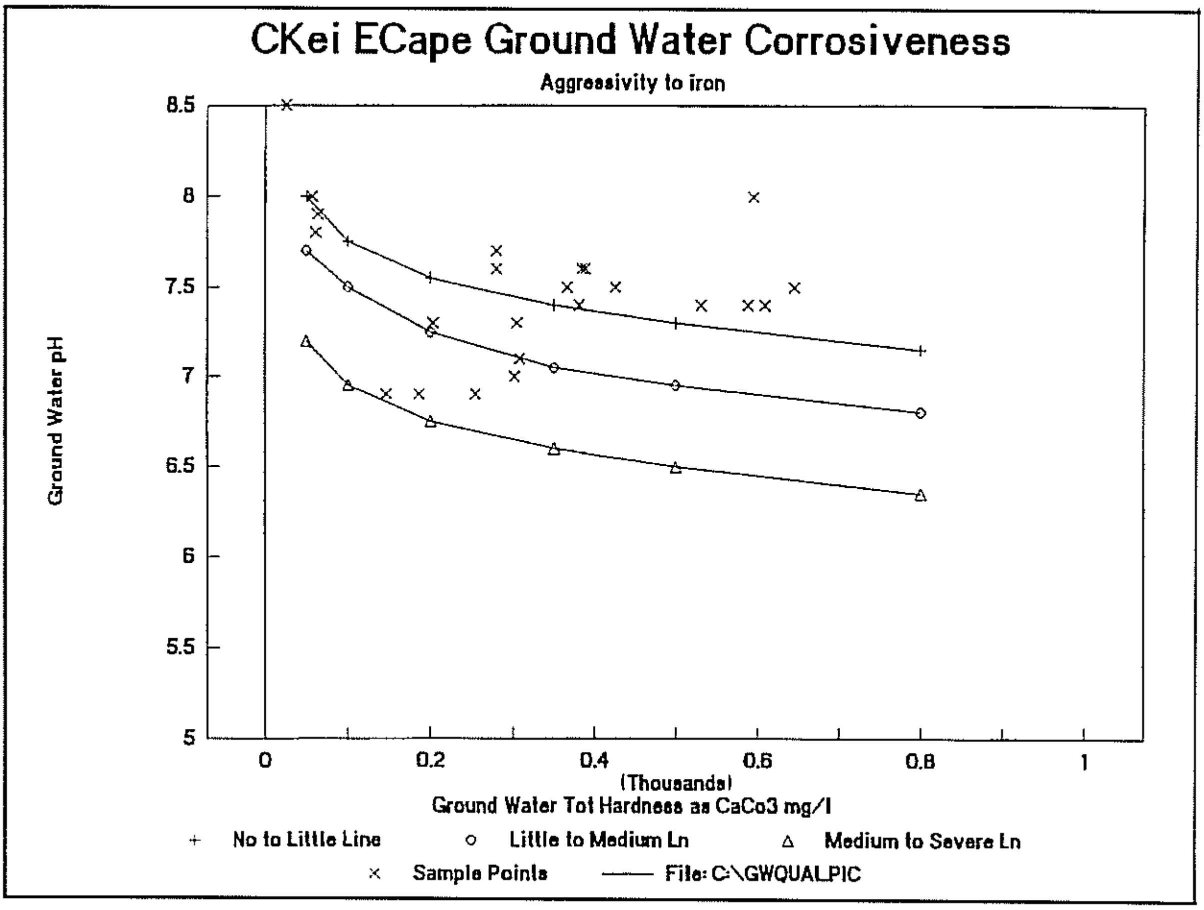


Figure 3.10 cont.: Aggressiveness of South African groundwater to iron

3.7 Handpump maintenance and the effectiveness of installations

In nearly all areas of South Africa, between 40 and 50% of the handpumps are not working at any one time. Mechanical breakdown of down-the-well or pumpstand components is usually the cause of failure, but in some cases, particularly at village level, it is not known whether failure was due to the borehole drying up or to mechanical breakdown.

North West Province is a general exception to this picture. There district-level maintenance teams are employed to look after all community water schemes, whether the pumping plant be engine-, motor-, wind- or hand-powered. It is easy to assume that the reason for this better maintenance record is the lack of alternative water sources, but even in North West Province it is important to realise that capable management made a conscious decision to place sufficient emphasis on the planning and implementation of maintenance and that policy makers gave them sufficient resources to carry out their plans. (Particularly for handpump installations, little cost recovery was implemented.) Without continued good management and the availability of back-up resources, the situation in North West Province could come to mirror the worst areas of the Eastern Cape and Northern Province.

Equally disturbing is the extremely poor condition of the majority of working pumps: long priming times in the morning because of leaking foot valves and seals; continued low yields with the reason (mechanical, or low borehole recovery rate) often not being clear; pump handle bearings worn right through; and pump handles loose at the point of attachment and often not the original ones.

The complete lack of institutional capacity at all levels, which results in little or no maintenance being carried out, is the obvious prime cause of the high failure rate. However, if this cause is eliminated, the significance of other causes would become obvious. These causes include the cheap way in which wells are drilled and not developed or tested, plus the fact that no attention is given to detail when pumps are purchased and installed.

Other factors which cause installations to be ineffective are: poor water quality (at source); poor water quality caused by corrosion of the pump components and the borehole casing; too many families served by each handpump for the capacity of the pump or borehole; and the siting of installations away from where villagers are living. These factors are often the result of the non-involvement of communities in decision making.

3.8 Cost recovery

The amount of cost recovery practised for handpump installations in South Africa is insignificant.

4 SURVEY OF HANDPUMP STAKEHOLDERS

4.1 Introduction

This chapter reports on the survey of handpump stakeholders - manufacturers, purchasers and user communities. This was done:

- to achieve better problem definition,
- to learn from the experiences of the different stakeholders, and
- to examine conflicting evidence and views before proposing a strategy for improving the effectiveness of handpump installations.

4.2 Handpump manufacturers

A list of 22 southern African manufacturers and agents for imported handpumps is given in Annexure B. Nine of these companies, all South African handpump manufacturers, were visited. All had well equipped facilities which have dependable quality control procedures in place. The products seen were robust but of conventional design which did not incorporate any VLOM concepts. Moreover, none of these manufacturers produced corrosion resistant handpumps and the one company which had been importing a corrosion resistant product had stopped promoting it.

The manufacturers visited claimed that there was no demand for either corrosion resistant handpumps or ones incorporating VLOM concepts. The findings set out in Section 4.3 suggest that this lack of demand is mainly due to purchasers buying on price and without a strict specification. The high initial demand for the Van Staden handpump, which incorporated both corrosion resistant and VLOM concepts at a competitive price, challenges the manufacturers' claim and it appears that sales of the Van Staden handpump only declined when some problems were encountered with the patented pump cylinder positioning mechanism.

Further evidence that corrosion cannot be ignored and that there is a need for corrosion resistant pumps for between 15% and 40% of South African applications is given in section 3.6, in which the corrosiveness of groundwater is analysed.

Also visited was an inventor developing a product incorporating both corrosion resistance and VLOM concepts. Whilst successful prototypes of this product have been built and tested under arduous field conditions by the inventor and a small group of competent users, production manufacturing techniques have not been developed.

When the factory visits took place the Barry Pump had not been developed (refer end of Section 3.2.3).

4.3 Handpump purchasers

4.3.1 The handpump purchasers' questionnaire

Annexure C is a copy of the questionnaire sent to handpump purchasers. The objectives of the questionnaire are summarised in the introductory notes to prospective respondents and in the aims of this project set out in Section 1.2.

In designing the questionnaire a balance was sought between specific factual information, more open evaluatory queries and structured evaluatory queries. It was also designed to cover the wide range of both institutional and technical issues which affect the effectiveness of handpump installations. It assumes that the respondent has a degree of technical knowledge.

4.3.2 How the survey was carried out and the response

The survey of handpump purchasers was carried out by post and fax. Fifty questionnaires were distributed in South Africa and forty over the rest of the world. Many of the contact addresses for persons outside South Africa were obtained from Erich Baumann of the Handpump Technology Network and SKAT Switzerland. This assistance is gratefully acknowledged.

Fifteen completed questionnaires were received from within South Africa and a further fifteen from outside. Seven further replies were received from recipients who did not complete the questionnaire and declared that they were no longer responsible for handpump installations. All the respondents had a technical background although the majority now hold managerial positions. Table 4.1 indicates the geographical and organisational spread covered by the respondents. In South Africa four of the questionnaires were sent to women, three of whom responded. Only one questionnaire was sent to India and sadly no reply was received.

Table 4.1: Handpump purchasers' questionnaire: location, gender and organisational affiliation of respondents

Region	No of replies	Gender		Organisational affiliation			
		Male	Female	Govern-ment	NGO	Consul-tant	Other
South Africa	15						
Northern Province	3	2	1	1	1	1	-
Gauteng	2	1	1	1	-	1	-
North West Province	1	1	-	-	-	-	1 Water Board
KwaZulu-Natal	4	4	-	1	1	1	1 Water Board
Eastern Cape	5	4	1	1	1	3	-
Rest of the world	15						
Asia	2	2	-	1	-	-	1 Foreign Aid Worker
West Africa (Ghana)	2	2	-	-	-	-	2 Foreign Aid Workers
East Africa (Uganda)	1	1	-	-	-	-	1 Foreign Consultant
SADC	10	10	-	4	3	-	2 UNICEF, 1 Contractor

As can be judged by the visual representation of replies to Section five given in Annexure D, the number and variety of respondents was satisfactory, and in all cases the feedback received was valuable. The time and care taken by each respondent in filling out and returning the questionnaire is gratefully acknowledged. The final conclusions and recommendations are, of course, the author's.

4.3.3 Details of pumps purchased

Table 4.2 gives details of the handpumps purchased by the various respondents.

In South Africa only 8 purchasers named the pumps they purchased. Half of these wrote of installation depths from 60 - 120 m. Three of these installed progressive cavity pumps for extra high head duties and two purchasers standardised on progressive cavity pumps for all duties. The fourth purchaser of extra high head pumps had purchased the Barry Pump for installation depths from 60 - 80 m. Other pumps purchased were Afridevs, India Mark IIIs, and standard non-VLOM lever- and double-wheel-operated piston pumps.

Table 4.2: Handpumps purchased by respondents

Region	Pump types	Installation depths (m)
South Africa	Afridev Barry Pump (1 purchaser only) Double wheel (1 purchaser only) India Mark III (small numbers only) Lever-operated Progressive cavity medium-head Progressive cavity high-head	0 - 60 60 - 80 not stated not stated 30 - 60 0 - 60 60 - 120
Asia	India Mark III India Mark V (also open-top cylinder VLOM-type) Afridev	20 - 40 40 - 60 0 - 30
Ghana	Afridev Nira	10 - 35 5 - 10
Uganda	Local derivative of the India Mark III	20 - 30
Botswana	Spare parts only	very deep
Lesotho	Progressive cavity India Mark III (for pilot evaluation projects)	very deep 0 - 40
Zimbabwe	Bush Pump (VLOM and non-VLOM models)	5 - 100
Other SADC	Afridev Tara	0 - 60 0 - 15

Thirteen of the "rest of the world" purchasers gave some details of the pumps purchased. With the exception of Botswana, Lesotho and Zimbabwe, all countries sought to standardise on VLOM pumps but the greatest installation depth quoted was 60m, half the South African figure. As can be seen from Table 4.2, two countries quoted maximum installation depths of as little as 30 and 35 m respectively.

Botswana reported that the water level in most boreholes is very deep and that handpumps are unpopular with users. Hence, only spares for existing installations are currently being purchased. In addition, nearly the whole country is now adequately supplied from motorised pumps.

In Lesotho, water levels also tend to be deep and handpumps are used as the last option after "gravity, power-pumped and solar systems". Traditionally, because of the deep water levels, most handpump installations are fitted with progressive cavity pumps, but Lesotho is now testing India Mark IIIs in districts where the water level is not so deep.

Zimbabwe has standardised on its own lever-operated piston Bush Pump recently modified to allow for an open-top cylinder. The earlier version was reliable to water depths of 100 m and the open cylinder version has been designed for the same duty.

Pump prices quoted in South Africa varied from R2700 to R5500. Outside South Africa variations were even greater and ranged from R 1 100 for a Tara direct action pump in Namibia, to R 1 600 for an India Mark III in Asia, to R 8 250 for an Afridev in Uganda.

4.3.4 Purchasing practice in South Africa

South African handpump purchasers overwhelmingly claimed that ease of use and high discharge rates were the most important criteria used when purchasing handpumps, although this is not borne out in their purchasing practice. These purchasers did, however, report that the feedback they had received from users with respect to both of these criteria was generally negative with respect to progressive cavity pumps and positive with respect to both India Mark IIIs and Afridevs. Leaking foot-valves causing priming difficulties and reduced discharge rates were reported by one purchaser of non-VLOM piston pumps. One Eastern Cape purchaser reported obtaining feedback that after 21 Afridevs had been installed in one district, users of 5 of the pumps were regularly trying to pump at rates in excess of the borehole recovery rate. On 3 of these pumps the drawdown was between 15 and 20 m . No changes were made to these installations and 9 months later they were still being operated in the same manner. In the other 2 cases the installation depth was only 3 or 4 m below the static water level and the installers added two more riser pipes to drop the pump cylinder 6 m . The users of these two pumps can no longer draw the water level down to the cylinder installation depth. **Whilst remembering that neither the India Mark III nor the Afridev are suitable for high head duties,** it is still important to note that users are demanding something other than progressive cavity type pumps for all duties.

The next most important criteria reported by South African handpump purchasers were reliability, robustness, durability, and guarantees. With respect to these criteria it was obvious that not all progressive cavity pumps were equal. Problem components included useless handle bearings, drive rod breakages and problematic anti-reversing ratchets. Other purchasers received positive feedback with respect to the reliability of progressive cavity pumps, even for extra high duties. Problems with rods breaking were also reported for a number of non-VLOM piston pumps. The limited feedback on India Mark IIIs was all positive. Feedback on Afridevs was mixed; some was positive whilst others reported that handles break off near the pivot point, fins on the piston valve break off and jam in the foot-valve, anchor bolts become loose in the concrete slab (stand option "b"), uPVC riser pipes shear off on deep water level installations, and rod joints wear rapidly at depths over 30 m . A limited number of Zimbabwe Bush Pumps were installed in South Africa in a pilot study. Whilst they generally worked well there was a problem in that children could not reach the handle at the top of the stroke. As a result they would let it go and some of the handles broke from slamming against the top stop.

Ease of maintenance, the availability of spares, and the general track record of the suppliers' after-sales service were also mentioned as being important. Feedback reports often complain about excessive time elapsing before repairs are carried out and in some cases also about the high cost of repairs.

In South Africa, generally neither the handpump users nor their water committees have been involved in the purchasing process. Some purchasers feel that they should be involved.

4.3.5 Purchasing practice in the rest of the world

In the rest of the world the most important criterion is following a national standard. Some countries have had quality control problems with both locally manufactured and imported pumps but purchasers have solved these problems through going back to the supplier within the guarantee period. Despite the aggressive standardisation policies, a few purchasers reported problems related to the availability of spares and lesser problems related to skills training. In Sri Lanka users have been asking for old handpumps to be replaced by open-top-cylinder ones.

Pakistan, Ghana, Uganda, Malawi, Namibia and Swaziland all reported mainly positive feedback whilst standardising on Afridev pumps, but the low installation depths must be noted. In Mozambique the earlier problems with breaking rod hooks and eyes have been overcome by changing the component supplier and material, but as the installed depth approaches 45 m there is still a high incidence of uPVC rising main joint and pipe fractures.

In Zimbabwe, where handpumps form the basis of supplying potable water to the rural areas, their own Bush Pump, designed and first installed in 1933, has been reported as a success for all lifts up to 100 m. Originally of a conventional design with a closed brass cylinder and galvanised-iron rising main, the Bush Pump has been gradually refined over the years and an open-top-cylinder version was officially endorsed by the National Action Committee of the Zimbabwean government in 1994. A special feature, worthy of note, is the manner in which the pumpstand is bolted to the borehole casing rather than to the concrete plinth. Also unique, but possibly not as applicable in other countries, is the use of a hardwood block for the lever handle and top pumprod bearing surfaces. The blocks are made of mopane or teak and are boiled in oil to provide self-lubricating properties. After being treated in this way these blocks last for 20 years in Zimbabwe before needing replacement. The mild steel pumprods are connected using case-hardened hook and eye joints. Although the response from Zimbabwe made no mention of groundwater corrosiveness, Morgan (1995, p.24) discusses using mild steel rods coated with a specialized epoxy resin, Copon EP2300 or Copon KS16W, to protect them against aggressive waters. With good quality control, such a coating is more effective than hot dip galvanising.

In both Botswana and Lesotho, which also have very deep wells and which, as reported in Section 4.3.3, rely more heavily than Zimbabwe on other technologies for supplying potable water to rural areas, users generally express their dissatisfaction with frequent breakdowns, poor maintenance services and the low level of service achieved with handpumps.

4.3.6 Operation and maintenance support in South Africa

In Northern Province the majority of handpumps have been installed by the Department of Water Affairs and Forestry (DWAF) or the old "homeland" administrations. Currently DWAF retains responsibility for the ownership and maintenance of all the handpumps installed by themselves. This is organised on a decentralised basis through about 50 decentralised workshops which are responsible for the operation and maintenance of rural water supplies generally and not just handpumps. The motivation of staff at these workshops, who may be transferred to local government in the future, is poor. They are also often ill equipped to carry out repairs when they arrive at an installation. The percentage of inoperable Departmental handpumps was reported as probably being in excess of 50%.

There are also a few isolated areas in Northern Province where handpumps have been installed with assistance from NGOs at the request of communities. Types of pump include many progressive cavity pumps and, more recently, India Mark IIIs and Afridevs. In these areas the communities own and are responsible for the upkeep of the pumps. On the insistence of the NGOs, small local contractors were employed by the pump suppliers to install these pumps. These contractors received further training from the pump suppliers in good installation and maintenance practice when required. Community members also received training in pump care, pump installation, water scheme management and book-keeping from the pump supplier and the responsible NGO acting as a team. At least two of the NGOs are continuing to monitor these installations and to support water committees motivationally in their management efforts. One of these NGOs claims that 95% of community-owned handpumps in its area of operation are currently operative but that close on 75% are still in a bad state of repair.

There was only one reply from North West Province and this was from a water board which carries out its own pump maintenance from three well equipped workshops. Most of the maintenance is carried out immediately after a community reports a breakdown. Simple day-to-day care of the pumps, all of which are non-VLOM, is done by the communities, but very little truly preventative maintenance is carried out. Between 85% and 90% of these pumps are operational at any one time.

In KwaZulu-Natal two parastatal joint services boards (JSBs) have introduced an innovative system for the maintenance of handpumps installed in their areas of influence. All the handpumps are handed over to village water committees after extensive caretaking and management/book-keeping training. Practically all the pumps installed have been of the progressive cavity type. In each of these areas the JSBs have awarded maintenance contracts to five local contractors by tender, with fixed rates for different tasks. These contractors do other work besides repairing handpumps. The JSBs, with the help of extension officers from the local Department of Agriculture, continue to monitor these pumps and give moral support to the village water committees. Communities are fully aware that neither the JSB nor the Department of Agriculture will ever pay for the repair of pumps although they will ensure that the communities are fairly treated by the maintenance contractors. The more dynamic of the two JSBs implementing this option, and the first to do so with the help of a consultant temporarily seconded to their office, states that 70% of pumps are in good working order at any one time. The other quotes a figure of 85%. Both JSBs are obviously proud of the extent to which their efforts have assisted rural communities in building up their self-reliance and ability to employ outside contractors, although they think their small internal budget to continue with low-key monitoring and motivational support will be important for some time to come. Disappointingly, one pump supplier has reported that these maintenance contractors have frustrated efforts made by consultants and community water committees to introduce VLOM pumps in the area.

In the rest of KwaZulu-Natal, with the exception of special pilot projects where Afridev, Vergnet and Barry pumps are being tried out, there is much confusion with respect to who is responsible for the maintenance of handpumps. This has been made worse by the large numbers of pumps which were installed in a great hurry when other traditional water sources failed during the 1982/3 and 1993/4 droughts. Currently purchasers estimate that in excess of 50% of handpumps are not working in most areas of the province.

The old Transkei and Ciskei governments took responsibility for the purchase of handpumps in the Eastern Cape and this responsibility has now been taken over by DWAF. The pumps are installed by contractors who in turn are managed by 8 traditional professional engineering consulting firms. In the absence of any maintenance budget, these consultants were asked by the Department to transfer full responsibility for the maintenance of the handpumps to the communities through a village water committee. Therefore, during installation the contractors are responsible for ensuring that village representatives selected by their water committees are trained to look after the pumps. "With what?" asks one of the management consultants in frustration - "at least some shear-legs and tools should be left in the villages." "VLOM pumps are a sham - they cannot work," writes another management consultant. No management or book-keeping training appears to take place, yet, on paper at least, water committees are responsible for employing a contractor to do maintenance work that cannot be handled by the village. In practice, if there is a major crisis and the water committee makes enough nuisance of itself a technician from the Department's District Office will come eventually to fix the broken pump "for free". Feedback on these technicians? - "an ineffective lot". Under the above circumstances it is not surprising that the percentage of inoperable pumps in the Eastern Cape was estimated to be greater than 50%, and by one management consultant "probably ... somewhere around 70%".

From the above it is evident that insufficient thought has been given to how communities are to be trained to look after installations and manage them and that too few resources have been allocated for that training. In addition it also appears that, despite wanting to help the rural communities more, the management consultants are generally out of their depth when dealing with rural development issues. They need to form partnerships with competent NGOs to make progress.

4.3.7 Operation and maintenance support in the rest of the world

In Sri Lanka the Central Government Authority sets standards and advises local government, which is responsible for major repairs. Each decentralised local government support group is responsible for keeping approximately 150 pumps in good working order. Pumps are handed over informally to beneficiary groups. Volunteers are trained to change washers, seals, etc. and to maintain the well environment in a hygienic condition. Beneficiaries have welcomed the introduction of open-top cylinders from India and are applying for older pumps to be replaced by these VLOM models. At any one time between 85 and 90% of pumps are in good working order. No comments were included as to how or what costs are recovered, especially by local government, but the word "volunteers" was used to describe the user group caretakers.

In Pakistan pumps are formally handed over to user groups, who sign a written agreement that they are responsible for all operation and maintenance. On-the-job training is carried out during installation. User groups can apply to send their user group maintenance person on a refresher course or to have a new one trained if the original maintenance person leaves the village unexpectedly. District-level government personnel do give free motivational support and technical advice but the village must always pay for the spare parts and do all the work themselves. There are no private contractors involved. Current estimates indicate that 85% of pumps are operable at any given time.

In Ghana pumps are only installed on demand and after the community has paid an initial fee to government. Pumps are handed over at official ceremonies to village water committees but there is no legal ownership framework. Experienced government-employed trainers train village-level caretakers and one mechanic to serve between 20 and 30 villages. Village caretakers are responsible for looking after pumps and reporting major failures to the local pump mechanic. In most cases these mechanics receive government funds to deal with major repairs. Spares are obtained by villages and local mechanics from local representatives of the pump suppliers. The percentage of pumps inoperable at any one time varies widely from area to area. It is usually between 30 and 50% but is as low as 10% in some areas.

In Uganda pumps are handed over to communities after the training of the water committee, the village-level caretaker and the private sector area handpump mechanic is complete. The private sector is responsible for all training, but at government expense. Area mechanics sign contracts with individual water committees to keep their pump in operation for a fixed fee. With this system over 90% of pumps are kept in operation at all times.

In Malawi pumps are handed over to village-level water committees consisting of both men and women. The Water Ministry, assisted by the Community Services and Health Ministries, is responsible for preventative maintenance and leadership training, which is all done at village level. Spares are purchased by user committees who care for their own pumps. Major breakdowns are reported to government area-monitoring assistants, who then assist communities to repair the pump themselves. Since the introduction of VLOM pumps, the care of non-VLOM installations has deteriorated due to the expectations of both village caretakers and area-monitoring assistants. As a result between 40 and 60% of these non-VLOM pumps are currently inoperable depending on the area. For the VLOM pumps the corresponding figure is between 10 and 15%.

In Namibia, water point committees are set up before pumps are installed. During installation the appointed caretaker is briefed on how to extract all the wearing parts from the Afridev VLOM pumps and how to re-install them. To ensure that the briefing has been fully understood and to help build up self-confidence, the caretaker is then required to strip the pump and re-install all the wearing parts before the installation/training crew leave site. This installation and training are done by the Department of Water Affairs operating from thirteen district-level offices. Pumps are then handed over to the water point committees complete with a full set of tools, spares, and operating and maintenance instructions. Local caretakers should be able to handle anything except a catastrophe, although the supply of spares has already been a problem in some districts. It is too early to quote inoperable figures as community training and VLOM pumps are new in Namibia.

In Swaziland all installation work and training is done by private contractors, who are usually appointed by foreign aid donors and occasionally by a government ministry. They are appointed on their track record for training and for keeping spares in stock as well as on their quoted price. The handpumps are handed over to the users by the contractor, complete with the borehole drilling records and the handpump manual, spares and tool-kit. After installation, training, commissioning and handover, contractors continue to monitor the installation and support the users for 12 months. Thereafter the users are on their own, but because Swaziland is a small densely populated country these users can always get assistance from their donor agency, a government officer or a contractor without difficulty. However, most problems are solved by the sale of spares to the users. There is no central monitoring of community water supplies in Swaziland. It is therefore difficult to estimate the percentage of installations that is inoperable at one time.

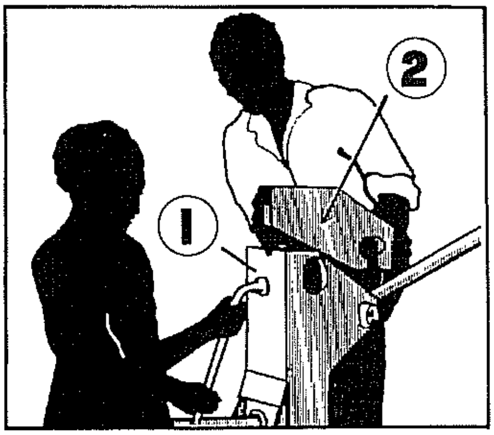
Mozambique has standardised on Afridev pumps. They are manufactured locally by one private company and the distribution of spare parts by commercial enterprises is being promoted. All installation, training and major repair work is carried out by the Provincial Rural Water Enterprises Ministry with some assistance from foreign NGOs. Pump caretakers are selected prior to installation. These designated caretakers first obtain training in hygiene awareness followed by practical training in how to keep the pump surroundings clean, the drainage and soakaway channels working and the fence protection in good repair. During the pump installation period they assist the government team to install the pump. They also receive training in maintenance procedures before, during and after the installation period. After installation, pumps are handed over at a ceremony to user communities complete with a set of tools, a spare parts kit, a plastic covered scheduled maintenance card (reproduced in Figures 4.1 and 4.2), and the Afridev Handpump installation and maintenance manual.

Whilst minor repairs are done by community caretakers, most major repairs are carried out by the government's provincially-based teams. Currently there are often delays before the repairs are carried out and it is hoped to decentralise these repairs to district and then local administrative levels as soon as practical. There are no reliable statistics available on inoperable pumps, but respondents commented that reports of up to 50% being inoperable are not uncommon. As reported in the literature survey, Afridev pumps are used in Mozambique to pump water from boreholes where the pumping head is in excess of 45 m, the maximum head for which the pump is designed. This, together with the currently over-centralised maintenance system, is probably responsible for the high percentage of inoperable pumps in Mozambique.

In Zimbabwe the government does not hand over the pumps to communities but has gradually, over the years, decentralised maintenance down to ward level. The maintenance is carried out by "pump minders" employed by the Ministry of Local Government and paid from what is commonly known as the District Development Fund. Since the introduction of open-top cylinders in 1994 "community-based maintenance" or "community-assisted maintenance" has been promoted and the government-employed pump minders have embraced it enthusiastically. Communities have also welcomed greater control over their water supply, but have been disappointed that the new VLOM pumps have a significantly lower output, caused

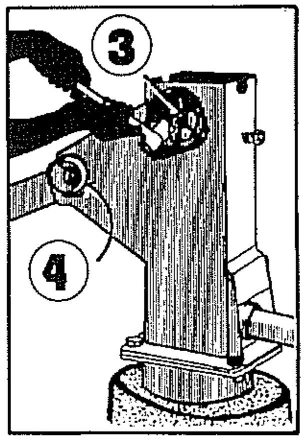
The Afridev Handpump. Scheduled Maintenance

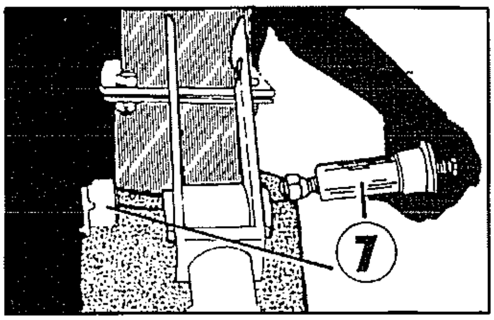
Scheduled Maintenance should be carried out at least once a year to ensure long life for the Handpump.

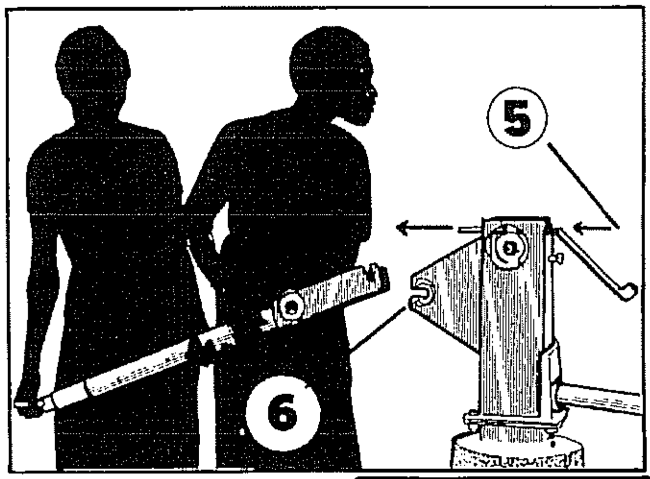


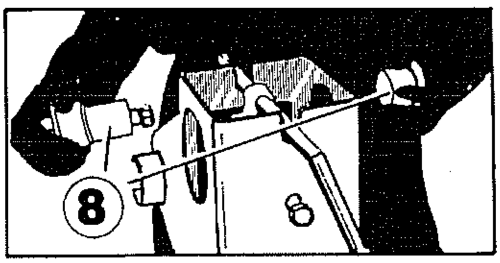
Before starting, remember to keep clean water for washing parts.

1. Loosen pumphead cover bolt.
2. Take off cover.
3. Loosen both hanger nuts.
4. Loosen both fulcrum nuts.
5. Put spanner through hanger eye.
6. Raise and withdraw handle.



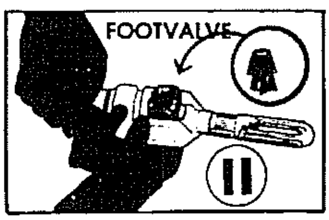






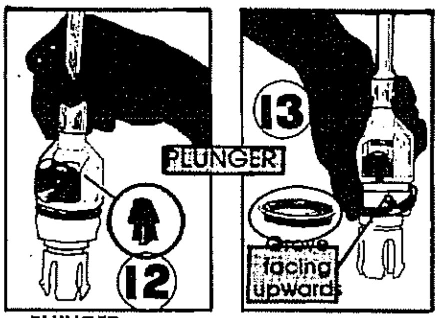
7. Remove fulcrum bearings and pin.
8. Remove hanger bearings and pin.
9. Pull up rods and plunger.
10. Join rods to fishing tool and lower down the well to pick up footvalve.
11. FOOTVALVE: Replace old bobbin with new.

All rods and pins should be washed before replacing.

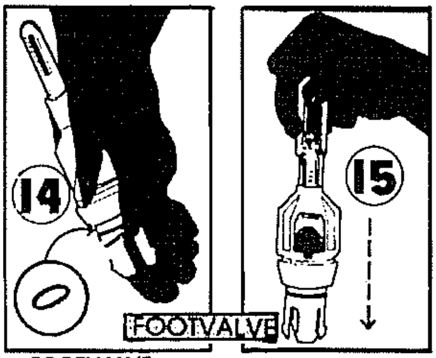


Keep all parts clean by storing in pumphead cover while repairing pump.

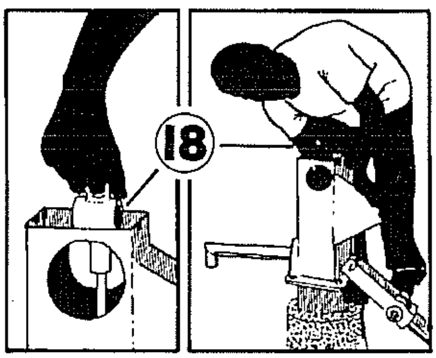
Figure 4.1: The Afridev Handpump scheduled maintenance card: front



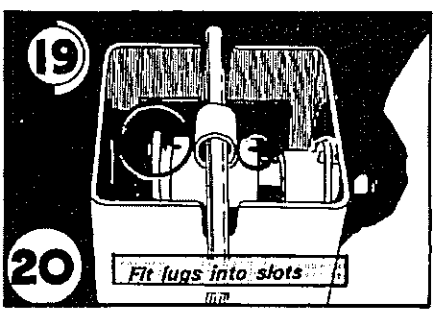
PLUNGER:
2. Replace old bobbin with new.
3. Replace old seal with new.

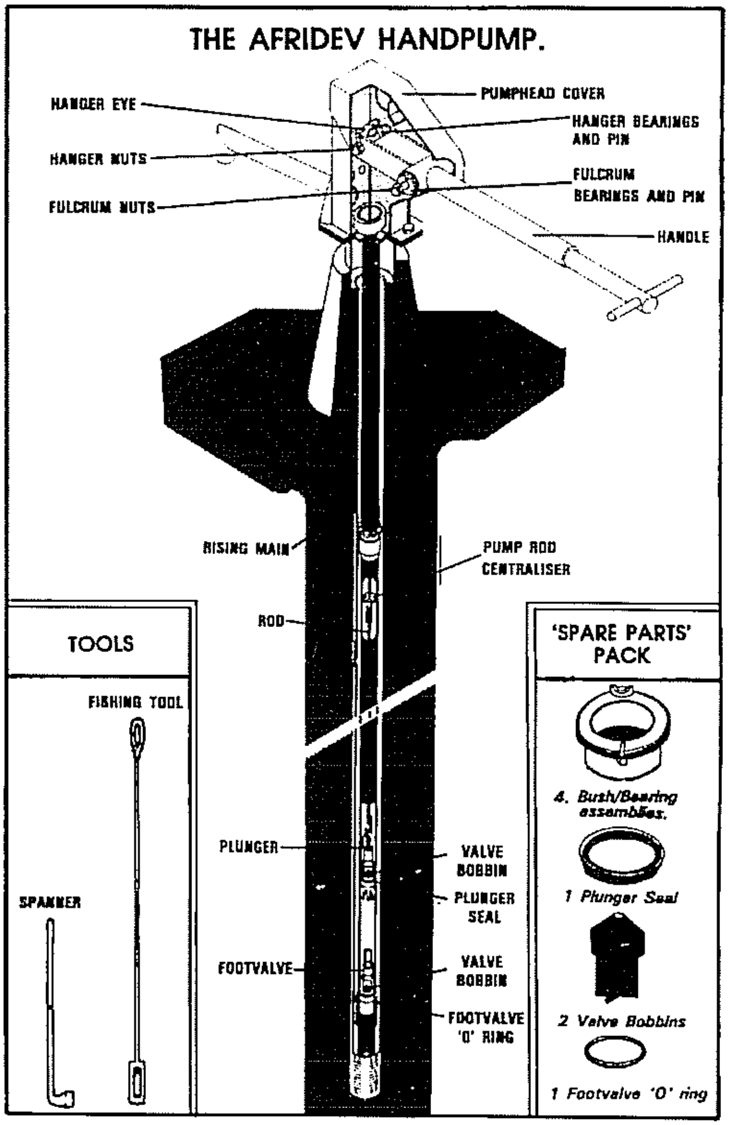


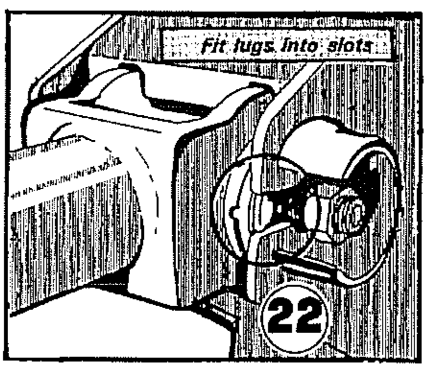
FOOTVALVE:
14. Replace old 'O' ring with new.
15. Drop footvalve down the well.
16. Put back plunger on rods. *(See No. 9)*
17. Join rods while lowering down the well.



18. Make sure that footvalve is in place by pushing the rods at arms length down the well.







19. Put spanner through hanger eye to support rods.
20. Put back hanger pin with new bearings.
21. Put back fulcrum pin with new bearings. *(See No. 7)*

22. Put back handle to support the hanger
23. Remove spanner and tighten all nuts.
24. Put back cover and tighten bolt.
25. Pump until clear water comes before drinking

Developed by Kwale Water & Sanitation Proj. (MoWD) Kenya with support and assistance from UNDP/World Bank, (Rural Water Supply Handpumps Project) with PATH and K.I.E. Card Designed and Illustrated by J. Waterkeyn (KWAHO) KENYA WATER FOR HEALTH ORGANIZATION. Issue No. 1 1988

Figure 4.2: The Afridev Handpump scheduled maintenance card: back

by keeping the old rising main size unchanged at 50 mm whilst reducing the cylinder from 75 mm diameter to 50 mm . More recently, a 65 mm version of the open-top cylinder Bush Pump has been developed. Hopefully, despite the slightly increased purchase price this newest version will be accepted by all stakeholders. Before the introduction of open-top cylinder pumps the percentage of inoperable pumps in Zimbabwe was estimated to be between 20 and 30%. With the introduction of open-top cylinders it is hoped to reduce this figure and the cost of maintenance.

The last 25 years have seen tremendous changes in Botswana so that today the GDP per capita is significantly higher than that of South Africa. Taxes are also higher, with central government's revenue as a percentage of the GDP being about double that of South Africa. The face of domestic water provision in Botswana has also changed drastically in the last 25 years, with 45% of the population now having individual household connections. In rural areas in particular, families who use less than 10 kℓ/month pay a very low lifeline tariff, whilst even the charges to those in the 10 - 25 kℓ/month category do not cover the full operation and maintenance costs of the supply. A further 30% of the population receive domestic water free from public standpipes to a standard at least equal to South Africa's minimum adequate RDP level. In the rural areas these schemes are maintained by decentralised district-level local government structures (Hazelton and Manganyi, 1997).

It is against this background that the use of handpumps is unpopular with both users and local government officials, with everyone demanding a service supplied from motorised pumps. Even existing handpumps are not being maintained, with at least 50% being inoperable. But beyond the dramatic success story of the water supplies to 75% of the population, there are still two problems: nearly 25% of the total population, most of whom live in un-gazetted villages with less than 500 inhabitants, do not have an adequate water supply and there are tensions caused by the fact that in all areas inhabitants are not allowed to use free domestic water for livestock watering. As in South Africa, it is unlikely that central government will achieve any acceptance of handpumps, should it so wish, whilst other users are obtaining a higher level of service free, but it is time that the inhabitants of un-gazetted villages shared in Botswana's success story. It appears that there are two options open. One: Extend public standpipe services to all for both domestic water supplies and livestock watering, provided Botswana is satisfied that this is nationally affordable in the long term. Two: Introduce a payment system for households obtaining their water from public standpipes. Electronic prepaid metering is a possible option to keep administration requirements to a minimum and to allow for the inclusion of livestock watering. To make this second option equitable and at the same time meaningful in terms of the amount of money collected from public standpipes, it may be necessary to introduce a fixed monthly charge for users having individual household connections, in addition to the current 3-tier tariff system. With all this in place, users could then choose which level of service to ask for, knowing that charges will relate meaningfully to the level of service provided.

Like Botswana and Zimbabwe, Lesotho relies almost exclusively on decentralised government services to keep its handpumps in working order. Like Botswana, but in contrast to Zimbabwe, Lesotho tends to relegate handpumps to the last choice when choosing a technology to supply a village with water. A positive reason for this is the availability of perennial streams with good quality water, which allows many villages to receive cheap and reliable water supplies from gravity schemes. This encourages other villages to demand a reliable and equally high level of service when no gravity supply is available. As a result, many engine-, motor- and solar-powered systems have been installed and much effort and money put into keeping them running effectively. Traditionally where handpumps were installed, Lesotho standardised on progressive cavity units because in a high percentage of cases water is pumped from depths in excess of 45 m. Generally users complain of the effort required to pump very little water, and of frequent breakdowns. However, the decentralised government repair service is relatively effective and a recent survey indicated that 74% of the handpumps were working. Corrosion is not a problem in Lesotho, and about 12 months before the survey was carried out Lesotho had installed a number of India Mark III pumps on a trial basis on holes with pumping heads between 20 and 40 m . These give a better discharge rate than progressive cavity pumps with less effort. Reliability monitoring is in progress but no results have been reported to date. Monitoring results reported in the literature survey would, however, indicate that a significant reduction in maintenance costs can be anticipated regardless of the exact number of interventions required. Improved pump availability as distinct from improved reliability may depend on how adequately the availability of spare parts has been organised (Arlosoroff *et al.*, 1987, p. 76).

Lesotho is looking to standardise on one type of pump, therefore it may have to look more widely to find the pump which best suits its needs. Does any Indian manufacturer make reliable, high discharge rate, open-top cylinder pumps capable of pumping from depths of 100 m? The Sri Lankan respondent to the survey wrote enthusiastically about an India Mark V pump manufactured by Meera and Ceiko of India, but it appears that it is only designed for pumping heads up to 60 m . How would Basotho users respond to the latest Bush Pumps from Zimbabwe, or should Lesotho, despite not having a corrosion problem, be looking at HDPE foot-operated pumps to get the best discharge rates at extra high head duties?

4.3.8 Purchasers' evaluation of statements about handpump systems

Section 5 of the purchasers' questionnaire required respondents to evaluate each of 32 statements related to the development of effective water supply systems using handpumps. Graphic representations of all responses are provided in Annexure D. A summary analysis of these results is given in Tables 4.3 and 4.4.

Table 4.3 lists the scores obtained from the respondents' evaluation of each of the 32 statements. Scores for South African and "rest of the world" respondents are listed separately. Possible scores ranged from 2 for "strongly agree" to -2 for "strongly disagree". A unanimous "strongly agree" or "strongly disagree" would result in a score of 30 and -30 respectively for each of the two groups of respondents, since each group comprised 15 respondents. A completely neutral response would result in a score of 0. The total scores obtained by adding the two groups together are also listed, as are the differences between each group's scores. This difference measures the divergence in views as expressed by each group. Each of the four columns also gives the absolute ranking of the replies in that column.

Standard deviations were calculated for the divergence in respondents' views for each of the 32 statements. The standard deviations will vary between 0 and 2 depending on the consistency of the set of reactions as follows:

0,0 reflects:	full agreement between all respondents
0,5 reflects:	half the respondents disagreeing by one degree e.g. half neutral and half somewhat agree
1,0 reflects:	half the respondents disagreeing with the other half by two degrees e.g. half neutral and half disagree by two degrees
1,4 reflects:	an equal spread of replies from respondents i.e. a completely random set of reactions
2,0 reflects:	maximum disagreement between the respondents i.e. half the respondents agree strongly and the other half disagree strongly.

Table 4.4 lists the standard deviations separately for each of the two groups of respondents and for the combined group. The last column shows the differences between the standard deviations of each group. A negative difference in this column indicates that the South African respondents were more in agreement when evaluating a particular statement than were the "rest of the world" respondents when they evaluated the same statement. Each of the four columns also gives the ranking and, where relevant, the absolute ranking of the standard deviations calculated.

Table 4.3: Handpump purchasers' responses to statements: analysis of responses

St. No.	Statement	Responses and abs. ranking of responses							
		RSA		Other		Totals		Difs.	
01	For installations to be effective, the community must be behind the choice of handpumps for their water supply.	20	**10**	10	**23**	30	**19**	10	**9**
02	Communities generally do not favour handpumps.	6	**26**	-8	**27**	-2	**32**	14	**4**
03	For handpump installations to be effective, the community must have chosen handpumps from a well informed position.	17	**14**	8,5	**26**	25,5	**20**	8,5	**13**
04	For handpumps to be effective, it is essential that the installation, from the drilling of the borehole to the setting of the handpump's cylinder at the correct depth, is professionally carried out.	26	**2**	26	**3**	52	**2**	0	**29**
05	Rural communities should receive adequate water supplies free and should only pay for water when individual households have yard connections.	-25	**4**	-24	**6**	-49	**4**	-1	**26**
06	Equitable cost recovery is an essential component of successful handpump installations.	12	**20**	22	**10**	34	**16**	-10	**9**
07	Full cost recovery, including capital repayments, is an essential component of sustainable handpump installations.	-8	**24**	-14	**20**	-22	**21**	6	**19**
08	Sufficient institutional capacity within a community to care for the pump(s) on a day-to-day basis is essential for sustainable handpump installations.	16	**15**	26	**3**	42	**9**	-10	**9**
09	Sufficient institutional capacity within a community to manage cost recovery is essential for successful handpump installations.	23	**7**	22	**10**	45	**6**	1	**26**
10	Before installing a handpump on a borehole, the yield of the borehole should be tested.	13	**18**	24	**6**	37	**13**	-11	**7**
11	Before installing a handpump on a borehole, the quality of the water should be analysed.	22	**8**	22	**10**	44	**8**	0	**29**
12	It is unreasonable to expect individual communities to be completely self-sufficient. It is therefore essential that any district in which handpumps are to be installed has an adequate repair network in operation.	19	**12**	16	**18**	35	**15**	3	**22**
13	It is unreasonable to expect individual communities to be completely self-sufficient. It is therefore essential that any district in which handpumps are to be installed has an adequate spares network in operation.	24	**6**	23	**8**	47	**5**	1	**26**
14	Community water supply schemes are a waste of good money. Only large centralised bulk schemes result in reliable rural water supplies.	-25	**4**	-20	**14**	-45	**7**	-5	**21**
15	Handpump installations should be carried out in a manner that allows the level of the water to be checked whilst the pump is still in the hole.	14	**17**	7	**28**	21	**22**	7	**16**
16	Being lighter and easier to handle, plastic riser pipes are ideal for community handpumps and should be used more widely.	12	**20**	18,5	**17**	30,5	**18**	-6,5	**18**
17	Because of problems with joining and general reliability, plastic riser pipes should only be considered when corrosion is a problem.	0	**31**	-16	**18**	-16	**25**	16	**2**
18	Communities generally do not favour handpumps because they have to walk long distances to collect their water.	2	**29**	-5	**29**	-3	**31**	7	**16**
19	Communities generally do not favour handpumps because they experience handpumps as being unreliable.	12	**20**	0	**32**	12	**28**	12	**5**
20	Handpumps are only useful as a back-up supply when other supplies fail.	3	**28**	-23	**8**	-20	**23**	26	**1**
21	We must standardise on one or two pumps in a given area.	13	**18**	20,5	**13**	33,5	**17**	-7,5	**15**
22	Pumps must be purchased to a strict specification.	16	**15**	26	**3**	42	**9**	-10	**9**
23	Pumps must be designed to facilitate community-level maintenance.	22	**8**	27,5	**1**	49,5	**3**	-5,5	**20**
24	Purchasers should use price as the sole criterion to decide which pump to purchase.	-27	**1**	-27	**2**	-54	**1**	0	**29**
25	The back-up service provided by the pump seller is an essential criterion to be considered when purchasing a handpump.	26	**2**	10	**23**	36	**14**	16	**2**
26	Pump corrosion can be ignored when purchasing a handpump.	-20	**10**	-20	**14**	-40	**11**	0	**29**
27	Pump abrasion can be ignored when purchasing a handpump.	-18	**13**	-20	**14**	-38	**12**	2	**24**
28	Progressive cavity pumps are superior to piston pumps for all handpump duties except maybe low heads up to 10 m.	-8	**24**	-10	**23**	-18	**24**	2	**24**
29	People generally want pumps that deliver the most water even if this makes them a bit more difficult to operate.	-5	**27**	-2,5	**31**	-7,5	**30**	-2,5	**23**
30	Ease of operation is more important than the rate at which water is delivered.	11	**23**	3	**30**	14	**26**	8	**14**
31	People prefer wheel-operated pumps to lever-operated pumps.	-1	**30**	-13	**21**	-14	**26**	12	**5**
32	People prefer lever-operated pumps to wheel-operated pumps.	0	**31**	11	**22**	11	**29**	-11	**7**

Table 4.4: Handpump purchasers' responses to statements: analysis of variations in responses

St. No.	Statement	Std. deviations and abs. ranking of deviations: RSA		Other		Totals		Difs.	
01	For installations to be effective, the community must be behind the choice of handpumps for their water supply.	1.01	**21**	1,44	**2**	1,28	**6**	-0,43	**10**
02	Communities generally do not favour handpumps.	1,54	**2**	1,71	**1**	1,69	**1**	-0,17	**23**
03	For handpump installations to be effective, the community must have chosen handpumps from a well informed position.	1,15	**15**	1,40	**3**	1,31	**5**	-0,25	**18**
04	For handpumps to be effective, it is essential that the installation, from the drilling of the borehole to the setting of the handpump's cylinder at the correct depth, is professionally carried out.	0,44	**30**	0,57	**27**	0,51	**31**	-0,13	**24**
05	Rural communities should receive adequate water supplies free and should only pay for water when individual households have yard connections.	0,79	**28**	0,80	**22**	0,80	**29**	-0,01	**29**
06	Equitable cost recovery is an essential component of successful handpump installations.	1,17	**12**	0.81	**19**	1,06	**17**	0,36	**12**
07	Full cost recovery, including capital repayments, is an essential component of sustainable handpump installations.	1.15	**15**	0.89	**18**	1,05	**20**	0,26	**17**
08	Sufficient institutional capacity within a community to care for the pump(s) on a day-to-day basis is essential for sustainable handpump installations.	1,29	**8**	0,40	**30**	1,02	**21**	0,89	**3**
09	Sufficient institutional capacity within a community to manage cost recovery is essential for successful handpump installations.	0,81	**25**	1,02	**15**	0,92	**25**	-0,21	**21**
10	Before installing a handpump on a borehole, the yield of the borehole should be tested.	1,50	**3**	0.80	**22**	1,26	**8**	0,70	**4**
11	Before installing a handpump on a borehole, the quality of the water should be analysed.	0,81	**25**	0.81	**19**	0,81	**28**	0,00	**31**
12	It is unreasonable to expect individual communities to be completely self-sufficient. It is therefore essential that any district in which handpumps are to be installed has an adequate repair network in operation.	1,00	**23**	1,29	**6**	1,16	**14**	-0,29	**15**
13	It is unreasonable to expect individual communities to be completely self-sufficient. It is therefore essential that any district in which handpumps are to be installed has an adequate spares network in operation.	0,80	**27**	1,02	**15**	0,92	**25**	-0,22	**20**
14	Community water supply schemes are a waste of good money. Only large centralised bulk schemes result in reliable rural water supplies.	0,79	**28**	1,25	**9**	1,06	**17**	-0,46	**9**
15	Handpump installations should be carried out in a manner that allows the level of the water to be checked whilst the pump is still in the hole.	1,18	**11**	1,20	**10**	1,22	**11**	-0,02	**28**
16	Being lighter and easier to handle, plastic riser pipes are ideal for community handpumps and should be used more widely.	1,33	**6**	1,00	**17**	1,17	**12**	0,33	**13**
17	Because of problems with joining and general reliability, plastic riser pipes should only be considered when corrosion is a problem.	1,32	**7**	1,12	**13**	1,33	**4**	0,20	**22**
18	Communities generally do not favour handpumps because they have to walk long distances to collect their water.	1,41	**4**	1.36	**5**	1,41	**3**	0,05	**27**
19	Communities generally do not favour handpumps because they experience handpumps as being unreliable.	1,17	**12**	1,26	**7**	1,28	**6**	-0,09	**26**
20	Handpumps are only useful as a back-up supply when other supplies fail.	1,72	**1**	0,81	**19**	1,60	**2**	0,91	**2**
21	We must standardise on one or two pumps in a given area.	1,36	**5**	1,08	**14**	1,26	**8**	0,28	**16**
22	Pumps must be purchased to a strict specification.	1,12	**18**	0,57	**27**	0,95	**24**	0,55	**7**
23	Pumps must be designed to facilitate community-level maintenance.	1,02	**20**	0,34	**32**	0,79	**30**	0,68	**5**
24	Purchasers should use price as the sole criterion to decide which pump to purchase.	0,40	**32**	0,40	**30**	0,40	**32**	0,00	**31**
25	The back-up service provided by the pump seller is an essential criterion to be considered when purchasing a handpump.	0,44	**30**	1,40	**3**	1,17	**12**	0,96	**1**
26	Pump corrosion can be ignored when purchasing a handpump.	1,01	**21**	0,77	**25**	0,92	**25**	0,24	**19**
27	Pump abrasion can be ignored when purchasing a handpump.	1,17	**12**	0,79	**24**	1,00	**22**	0,38	**11**
28	Progressive cavity pumps are superior to piston pumps for all handpump duties except maybe low heads up to 10 m.	1,09	**19**	1,20	**10**	1,15	**15**	-0,11	**25**
29	People generally want pumps that deliver the most water even if this makes them a bit more difficult to operate.	1,25	**9**	1,26	**7**	1,26	**8**	-0.01	**29**
30	Ease of operation is more important than the rate at which water is delivered.	0,85	**24**	1,17	**12**	1,06	**17**	-0,32	**14**
31	People prefer wheel-operated pumps to lever-operated pumps.	1,24	**10**	0,72	**26**	1.09	**16**	0,52	**8**
32	People prefer lever-operated pumps to wheel-operated pumps.	1,15	**15**	0,57	**27**	0,98	**23**	0,58	**6**

Table 4.5: Handpump purchasers' responses to statements: the eight statements which elicited the highest scores from all respondents combined

Response ranking	Response "score"	St. no.	Statement
1	-54	24	Purchasers should use price as the sole criterion to decide which pump to purchase.
2	52	04	For handpumps to be effective, it is essential that the installation, from the drilling of the borehole to the setting of the handpump's cylinder at the correct depth, is professionally carried out.
3	50	23	Pumps must be designed to facilitate community-level maintenance.
4	-49	05	Rural communities should receive adequate water supplies free and should only pay for water when individual households have yard connections.
5	47	13	It is unreasonable to expect individual communities to be completely self-sufficient. It is therefore essential that any district in which handpumps are to be installed has an adequate spares network in operation.
6	45	09	Sufficient institutional capacity within a community to manage cost recovery is essential for successful handpump installations.
7	-45	14	Community water supply schemes are a waste of good money; only large centralised bulk schemes result in reliable rural water supplies.
8	44	11	Before installing a handpump on a borehole, the quality of the water should be analysed.

Examining the eight statements which elicited the highest scores from respondents helps us to focus on the issues which are most likely to frustrate the implementation of effective community water supply systems using handpumps.

- At the top of Table 4.5, which lists the eight statements that elicited the highest scores from all respondents combined, comes the warning not to purchase handpumps on price alone. The "rest of the world" respondents ranked statement 22, the need for a strict specification, 3rd, and these two responses need to be taken as a single recommendation.
- Second comes the need for carrying out the entire installation professionally, not just the choosing of the handpump. Many of the comments in the literature survey, in particular the comments of Banda (1997), are of note in this regard.
- Thirdly, pumps must be designed to facilitate community-level maintenance, an issue which to date has largely been ignored in South Africa.
- Four reflects the acute need for adequate cost recovery.
- Five reflects the need for an institution or organisation embracing a number of villages to ensure that an adequate spares network is in operation to support village- and local-level maintenance in any area where handpumps are installed. It is instructive to note that both South African and the "rest of the world" respondents saw the need for an adequate **spares** network as being more critical than the need for an adequate **repair** network. (For the latter refer Table 4.3, statement number 12.) The issue of day-to-day care of pumps is dealt with separately under statement number 08 (refer Table 4.3) and should be understood in the context of the strong response to the need for handpumps purchased to be designed for community-level maintenance (ranked third above).

- Six reflects the need for institutional capacity at village level to implement the cost recovery recommended in the fourth item above.
- Seven reflects the respondents' confidence in the effectiveness of small community water schemes as against larger regional schemes. However it is important to note from the judgement of statements 02 and 20 (refer Table 4.3) that, despite the respondents' confidence in small community schemes generally, this confidence does not extend to handpump installations. Hence the need for additional care when implementing community handpump projects.
- Eight reflects the need to analyse the quality of the water in a borehole before installing a handpump. The importance of this criterion extends beyond health issues to corrosion and abrasion, which in turn can affect the choice of borehole casing and handpump construction materials.

4.3.9 Examination of the two statements which elicited the greatest divergence between South African and "rest of the world" respondents

This section examines the two statements which elicited the greatest difference in response from the South African and the "rest of the world" respondents. These two statements are reproduced in Table 4.6.

Table 4.6: Handpump purchasers' responses to statements: the two statements which elicited the strongest divergence in reactions between South African and "rest of the world" respondents

Response divergence ranking	St. no.	Statement
1	20	Handpumps are only useful as a back-up supply when other supplies fail.
2	25	The back-up service provided by the pump seller is an essential criterion to be considered when purchasing a handpump.

The first statement elicited a -23 score from "rest of the world" respondents, ranking 8th in importance of "rest of the world" responses. The negative sign indicates that they disagreed with the statement. This was in sharp contrast to South African respondents, who on average marginally agreed with the statement.

This contrast can reflect at least three possibilities. **One:** South African villagers' expectations are so high that handpumps are indeed only useful for back-up duties. **Two:** The expectations of users elsewhere are just as high as South African users but the purchasers, 40% of whom appear to be temporary residents of the country on whose behalf they are responding, are less aware of the users' expectations. **Three:** South African purchasers have, on average, a more intensely negative attitude towards handpumps than the users. Whilst the users' survey does reflect some clearly negative attitudes towards handpumps, these negative attitudes centre most strongly around the reliability of the current installations and the water delivery rate (refer Figure 4.7). Thus the users' survey essentially confirms the third possibility. Purchasers should therefore guard against having such intensely negative perceptions unnecessarily, since such perceptions will seriously increase the problems of implementing an effective handpump maintenance programme, one of the essential components of developing sustainable community water supply.

On the other hand, the first and second possibilities should not be ruled out completely, and purchasers should be sensitive enough to be aware of communities' long-term aspirations, and when short-term expectations are high. Only then will the purchaser be able to handle negative community attitudes when the improvement of an existing handpump installation is the only immediate solution available to a village.

It should also be noted that whilst six South African respondents agreed strongly that handpumps are only useful as a back-up supply, four disagreed strongly. (Refer to statement 20 in Annexure D and note the large standard deviation for South African purchasers in Table 4.4.) Two recent experiences of the author point to a complex relationship between what is paid for water, perceived benefits and the acceptance of different systems by the majority of users.

The Sinthumule/Kutama Regional Water Project in Northern Province was commissioned recently. It is an extensive reticulated scheme with water available to all users within 200 m walking distance. The water source for the project is local groundwater, which is brackish. During a mass meeting with community members on cost recovery, it became clear that people anticipated that operation and maintenance costs would be appreciably higher than for a well-maintained scheme using handpumps and that if the water was coming from the same source they were unsure that the additional costs were worth it. Then quite spontaneously they asked "Are the pipes going to reach to where we water our cattle?" They were told that currently there were no plans to extend the pipes but that it could be considered if there was a demand. A short discussion ensued, after which there was a unanimous declaration: "Then the handpumps must stay, for the cattle."

Modderspruit in North West Province is another scheme. The Water Authority, the Eastern District Council, purchases water from Rand Water for the scheme. It was commissioned in February 1997 and during February and March the whole village used the new scheme with few households paying anything for the water. Then in April and May an electronically-operated prepayment scheme was introduced. Immediately the water demand from the new scheme dropped by a factor of six, because more than half the households in the village reverted to using the old public and privately owned handpumps already installed in the village before the new scheme was commissioned. The majority of the other households only use water from the new scheme for drinking, cooking, and washing eating utensils. Households are not paying anything for the water obtained from the public handpumps and the community (in contrast with the village RDP committee) has made it clear that they do not want these pumps removed.

The second statement that elicited a very different response from the two sets of respondents relates to the high importance South African purchasers place on the back-up service provided by the pump seller, compared with the relatively low importance accorded this service by the "rest of the world" respondents. The difference may well relate to the respondents' differing experiences, since the majority of pumps purchased by the "rest of the world" respondents are manufactured to public domain designs, whilst South African respondents purchase pumps from manufacturers who are selling their own products. In the latter case the tradition of supporting the brand name, Climax, President or Mono, for example, appears to be much stronger than in the case of manufacturers of public domain pumps, which are sold as India Mark IIIs or Afridevs.

Thus South African water authorities need to consider the likelihood of less support from the seller when adjudicating tenders for the purchase of public domain pumps. On the other hand, South African water authorities are currently relying too heavily on sellers supporting their products rather than forming a more equal partnership to ensure that spares are available when needed and that pumps are properly maintained.

4.4 User communities

4.4.1 The handpump users' questionnaire

Annexure E is a copy of the questionnaire used to interview pump users. The annexure is complete with the notes written to help the interviewer with his/her task. The aims of the handpump users' questionnaire were to find out how users view their handpump installations, what their preferences are and what critical problems, both technical and institutional, they have which prevent handpumps from being an effective means of supplying them with water. The questionnaire covers specific factual information, structured evaluatory queries and open evaluatory queries. Overall, the handpump users' questionnaire was quite ambitious but the shortage of detailed information in the literature surveyed motivated the project team to strive for high value results.

4.4.2 How the survey was carried out

Two sets of questionnaires were issued.

The first set was issued to a technician based at the CSIR's facility near St Lucia along the North Coast in Natal. The technician is employed full time transferring technology to local rural communities who are improving their own water supplies through donor-assisted capital projects. The technician was briefed by two water supply engineers based at the same facility. These engineers had discussed the questionnaire with the author in Pretoria but the technician had no such direct contact. The technician conducted 10 interviews after which the author stopped him doing any further interviews as the quality of the work was unsatisfactory. These interviews were discarded and are therefore not included in the analysis described below.

The second set of questionnaires was issued to a group of 12 female final-year sociology students from Pretoria University. The students were accompanied into the field by a senior sociologist from the CSIR and one of their senior lecturers from the university. The senior sociologist had been briefed by the author. The students spent two days in the field and conducted the group interviews in pairs. Forty-three completed questionnaires were returned and all have been included in the analysis set out below. The interviews were conducted in fifteen villages in the Southern District of Northern Province.

The students interpreted the instruction "we need the handpump users' evaluation of their own situation" literally. Therefore, no attempt was made by the students to check the veracity of statements made by users by, for example, testing the pumps themselves or drawing the users out more if the answers were unclear or even contradicted an earlier answer. On the other hand many comments that users made on the questionnaire, and additional comments made when only a yes/no answer was called for, were recorded. Thus an accurate record of users' spontaneous thoughts and feelings has been recorded, rather than an accurate factual picture or one which sets out to solve the tensions expressed by some community members when, for example, they were asked in question 2.3 to state which of two problems was the "bigger problem" for the community.

Overall results of greater value could be obtained if the pairs of interviewers comprised one sociologist and one technologist with a good understanding of groundwater and handpumps. However, such a combination would only improve the overall results if the sociologist still managed to allow the users to express all their thoughts and feelings as they did and only allowed the technologist to add value at the end of the interview by clarifying some of the factual issues. Broadly, therefore, the students did well in allowing the users to be heard and faithfully recording their views.

4.4.3 Description of the sample

The villages in which the interviews took place varied in size from fewer than 100 families (half the villages) to between 300 and 500 families. All but one of the fifteen villages rely on one or more handpumps for all water from an "improved" source. In one village even the handpumps were relatively new and had never broken down. This village did not report reliability or the time taken to repair handpumps as being a problem but every other village had some comment to make in this regard. Corrosion is a problem in the area and some respondents reported using or purchasing river or external tap water for washing clothes.

A total of 322 people took part in the interviews: 12 pensioners, 33 men, 87 women and 190 children, but no pump caretakers. The number of people in the groups being interviewed varied between 1 and 23. Seven of the groups included pensioners, 16 included men, 29 included women and 24 included children. Despite their large numbers, children were only in the majority at 15 out of the 43 interviews.

In interpreting these results it must be borne in mind that all the interviews were carried out in one small area of Northern Province and therefore may not be representative of South Africa as a whole. This is in sharp contrast with the results of the pump purchasers' survey, where, despite the small sample, an excellent geographical and organisational spread was obtained. Some additional comments on the wider applicability of the data are included in the text which follows where such comments are considered helpful.

4.4.4 Pumps used and preferences

The groups were asked to indicate which types of pump they used and which pumps they preferred. They were helped to identify the different types of pumps by means of cards with pictures of the different types, as shown in Figure 4.4. These pictures are reproduced in full size in Annexure E.

Figure 4.3 shows the number of each type and sub-type of pump used. The total number of pumps exceeds the number of groups interviewed because many groups use more than one type of pump. It can be seen from Figure 4.3 that standard lever-operated piston pumps were used more than any other type. Groups used wheel-operated piston pumps to a surprising degree, especially ones with a large wheel rather than a small wheel. Lastly they used rotary screw pumps, especially direct-drive ones rather than those fitted with a gearbox.

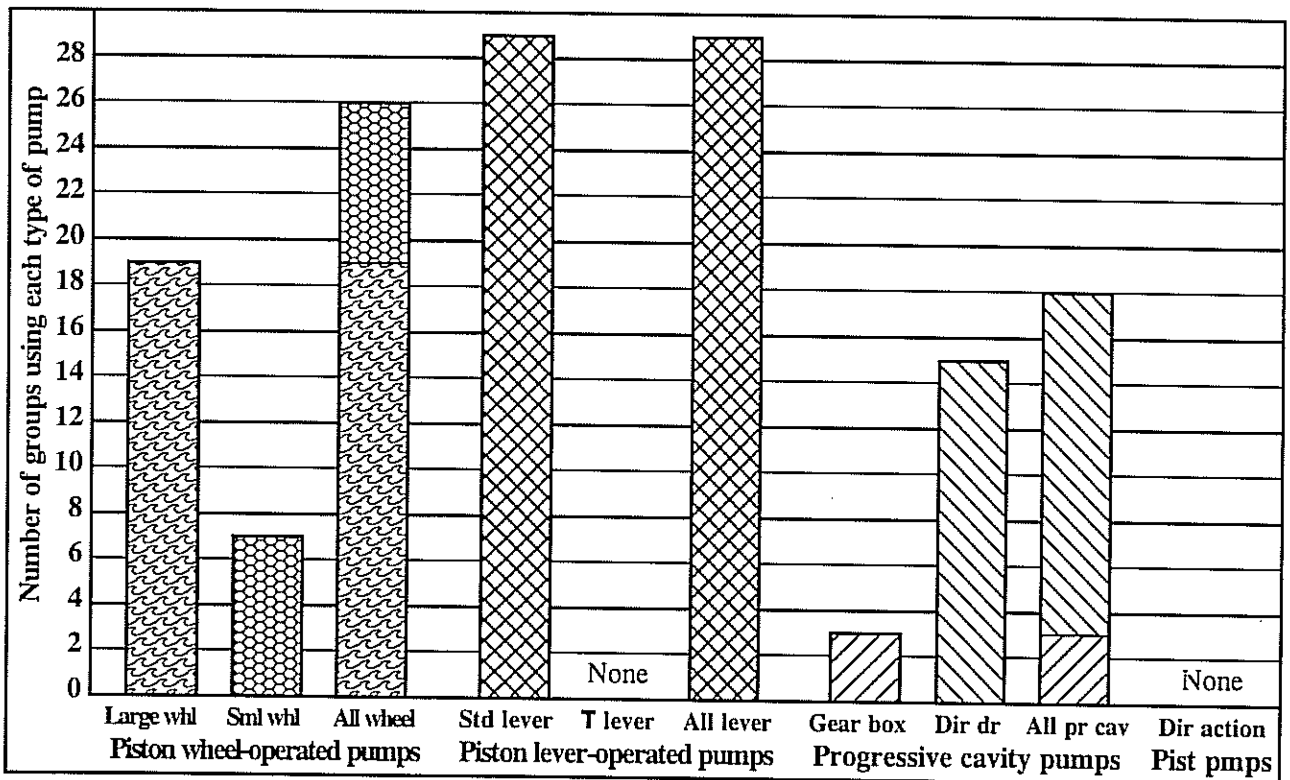
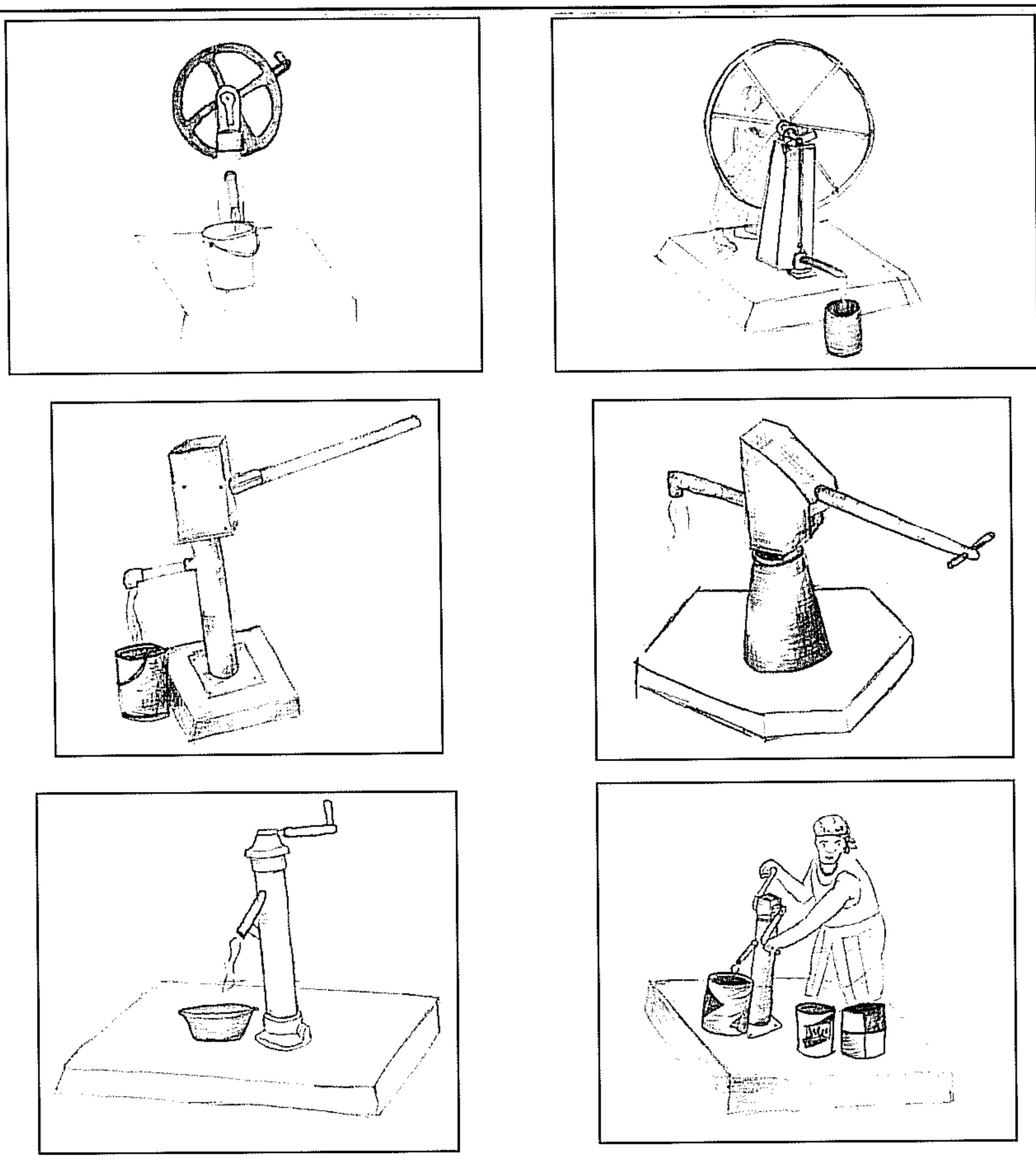


Figure 4.3: Handpump users' survey: types of pump used by the user groups interviewed

Users were asked to express their preferences between the types of pumps they used or, in the case of non-users, that they were familiar with. They were first asked to choose which sub-type they preferred, and then to rank the main types in order of overall preference. First preferences expressed by users and



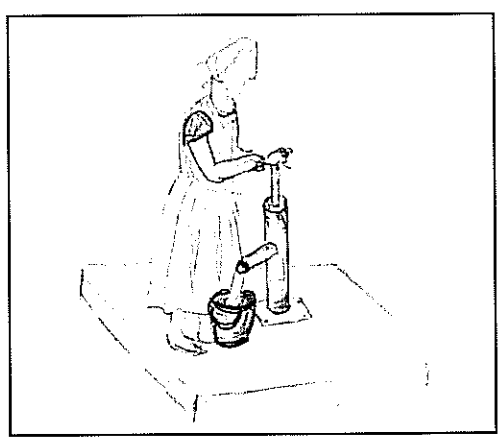


Figure 4.4: Pictures used to help handpump users identify pump types

non-users were examined separately. This was done to check users' loyalty to the pumps they used and to ensure that such loyalty did not bias percentages in favour of the most commonly used pump in the area. Details of the preferences are given in Table 4.7 and repeated graphically in Figure 4.5. These preferences show that user loyalty is not strong. They also show that a significantly large percentage of non-users chose lever-operated piston pumps as their first preference whilst a low percentage of non-users chose rotary screw pumps. Thus the overall first preferences are a reasonable indication of the preferences for the three main types of handpump used in the area where the interviews took place.

Table 4.7: Preferences expressed for different types of handpump

<table>
<tr><th rowspan="2">Pump</th><th colspan="2">Wheel piston</th><th colspan="2">Lever piston</th><th colspan="2">Rotary screw</th><th>Piston</th></tr>
<tr><th>Large</th><th>Small</th><th>Std.</th><th>T</th><th>Geared</th><th>Direct</th><th>Direct</th></tr>
<tr><td rowspan="2">Number of user groups</td><td>19</td><td>7</td><td>29</td><td>0</td><td>3</td><td>15</td><td>0</td></tr>
<tr><td colspan="2">26 = 100 %</td><td colspan="2">29 = 100 %</td><td colspan="2">18 = 100 %</td><td>N/A</td></tr>
<tr><td rowspan="2">User groups' first preferences</td><td>7</td><td>0</td><td>13</td><td>N/A</td><td>1</td><td>6</td><td>0</td></tr>
<tr><td colspan="2">7 = 27 %</td><td colspan="2">13 = 45 %</td><td colspan="2">7 = 39 %</td><td>N/A</td></tr>
<tr><td>Number of non-user groups</td><td colspan="2">17 = 100 %</td><td colspan="2">14 = 100 %</td><td colspan="2">25 = 100 %</td><td>43 = 100 %</td></tr>
<tr><td rowspan="2">Non-user groups' first preferences</td><td>2</td><td>2</td><td>3</td><td>3</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td colspan="2">4 = 24 %</td><td colspan="2">6 = 43 %</td><td colspan="2">3 = 12 %</td><td>3 = 7 %</td></tr>
<tr><td>Total number of groups</td><td colspan="7">43 = 100 %</td></tr>
<tr><td rowspan="2">Overall first preferences</td><td>9</td><td>2</td><td>16</td><td>3</td><td>2</td><td>8</td><td>3</td></tr>
<tr><td colspan="2">11 = 26 %</td><td colspan="2">19 = 44 %</td><td colspan="2">10 = 23 %</td><td>3 = 7 %</td></tr>
</table>

Consideration was given to making a quantitative analysis of groups' last preferences, as a measure of negative votes. This exercise was abandoned when it was noted that 18 out of the 43 groups interviewed did not give a third or fourth preference. A large majority did not give a fourth preference but this is because most users were unfamiliar with direct action pumps and therefore were not asked to include them in their ranking.

Reasons offered for rejecting wheel-operated pumps were:

- Wheel-operated pumps with a small wheel have no definite advantages over lever-operated.
- Whilst large wheels are smoother for adults to operate when they are in good condition, they are more difficult if not impossible to operate once the wheel bearings get worn.
- Despite the smoothness, an adult feels cramped when operating a large wheel pump and it is very difficult for two people to operate it together.
- Young children cannot turn the handle right round when the water is deep.
- If a hole is running dry or very little water is coming out, children love to turn the handle really fast and this damages the pump, especially the bearings.

Comments offered on standard levers versus **T**-shaped levers:

- "The **T** would get in the way and make it more difficult for two people to operate the pump."
- "I would like to try one with a **T**-handle, maybe it would be easier to use."

Comments offered on rotary screw pumps:

- "The water comes out too slowly."
- "They are awkward to operate."

Direct action pumps: A few respondents liked the idea of a simple pump with fewer parts to go wrong and maybe delivering "lots of water".

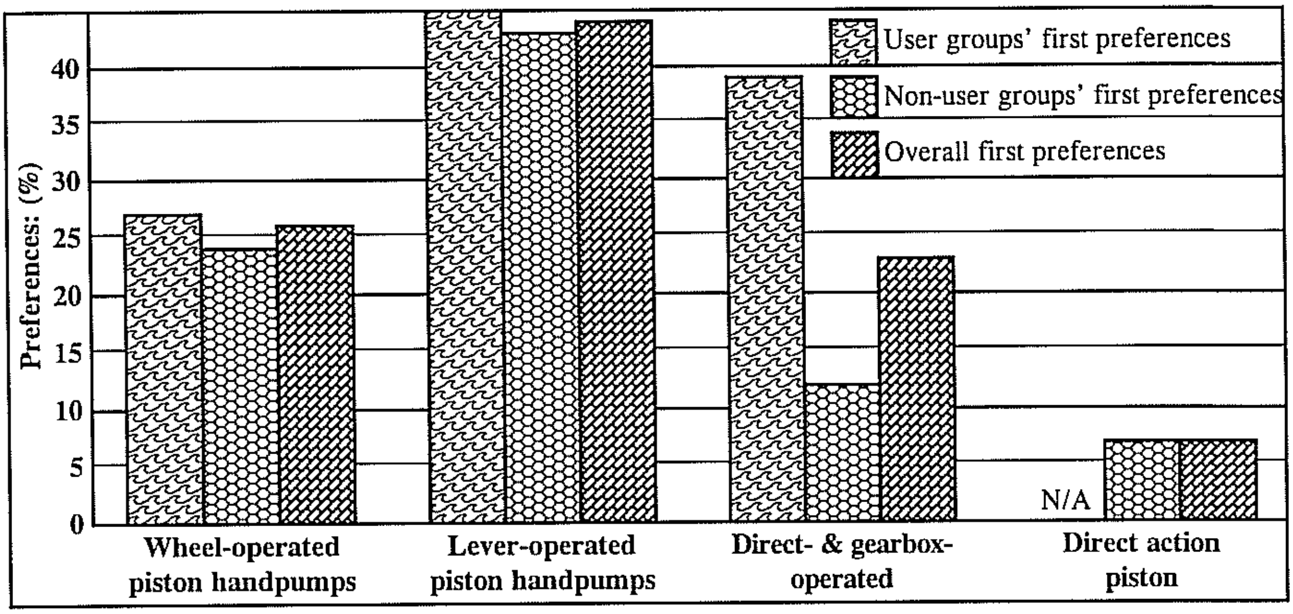


Figure 4.5: Interviewed groups' percentage preferences for three broad categories of handpump

The arguments with respect to why users do not favour wheel-operated pumps would appear to have wide applicability. In addition large wheel pumps are generally the most expensive pumps to produce. Manufacturers of these pumps should therefore ensure that they have corresponding lever-operated models to take full advantage of users' preferences. It should also be noted from Table 4.7 that small wheel pumps are even less popular than large wheel pumps. It would therefore seem appropriate to phase out the manufacture of these pumps.

The comments of users on rotary screw pumps combined with the feedback from the handpump purchasers indicate that rotary screw pumps are also less popular than lever-operated pumps and that their use should be discouraged except for non-corrosive extra-high-lift duties in the short term. It is also interesting that in the area where the interviews took place users did not report any definite advantage for the geared type over the direct-drive type, despite the former being capable of delivering more water. If consideration is being given to installing a rotary screw pump in a village, it would be wise to consult the future users first, both with respect to the basic choice of a screw pump and as to which model should be installed.

The difference between a standard and a **T**-shaped lever does not seem to be critical but the comment about more than one operator is worth noting. Another method of achieving user-friendly two-person operation is by fitting a double lever handle which extends from both sides of the pumpstand. Such a pumpstand, with counterweights attached to the lever on the standard side to equalise the work required of each operator, has been designed and manufactured in South Africa for use with a 45 to 100 m head handpump (WESA, 1993)

In the area where the interviews took place it is unlikely that the water table level is suitable for the use of direct action pumps but the positive response of the few respondents who commented on the possible use of such a pump should be noted.

Given the likely advantages of foot-operated pumps for South Africa, as described in the literature survey, the lack of any reference to such pumps in the users' survey requires some comment. The reasons for the omission are a lack of experienced users to interview, and the late realisation of the need to investigate the use of these pumps. However, the low loyalty of users to their existing handpumps indicates that users would evaluate foot-operated pumps objectively, despite their lack of experience and familiarity with such units.

4.4.5 Problems preventing handpumps from being truly effective

In Section 2.2 of the handpump users' questionnaire, communities are asked to describe the things which they dislike most about their handpump installations or which give them problems. They are subsequently prompted about possible problems they did not mention. The number of responses for each dislike/problem is shown graphically in Figure 4.6.

Apart from the 10 probable dislikes/problems listed on the questionnaire, user groups also spoke about the following problems unsolicited:

- "The water source dries up or does not have enough water." (3 groups)
- "Children cannot operate the pump or find it very difficult." (2 groups)
- "We need more pumps in the village." (2 groups)

Referring to the dislikes/problems reported in Figure 4.6, all those referring to the disagreeable taste of the water said it tasted salty. With respect to the few reports stating that the water was unhealthy, users said it caused constipation and turned their teeth brown. None of the users mentioned diarrhoea with respect to the water pumped by the handpumps, but one mention was made of the danger of getting typhoid when the handpumps are not working. With respect to the bad colour of the water, a few users stated that it was impossible to wash clothes in the water because of staining. In addition the soap did not work properly. There were also comments about parts down the hole getting rusty and causing pumps to break down. It therefore seems likely that the water in the area where the interviews took place is corrosive and that some of the water quality problems reported are due to the use of inappropriate non-corrosive-resistant pumps.

From Figure 4.6 it is not clear whether users want pumps which are easy to operate but which pump water at a low rate or pumps which are more difficult to operate but deliver water at a higher rate. Section 2.3 of the handpump users' questionnaire looked more closely at this problem by asking users to compare and rank these conflicting requirements. Figure 4.7 makes it clear that most users prefer a high delivery rate pump to one that is easy to use. In discussing this choice it became clear that to users a "difficult pump" is generally one which takes a long time to prime and then delivers very little water because of the endless leaking of water back into the hole. No matter how easy it is to move the actuator on such a pump, users describe the prolonged effort as frustrating and tiring. A short tough task is much preferred, with the proviso that children must be able to pump some water. A "difficult pump" was rarely taken to mean one requiring excessive force to operate. This is probably because the former problem of leaking valves and seals is much more common.

If users state directly that a pump is not pumping enough water, it is most likely to mean that they are asking for an additional pump or that they think the borehole recovery rate is preventing more water from coming out, rather than that they think there is something wrong with the pump or the pump design.

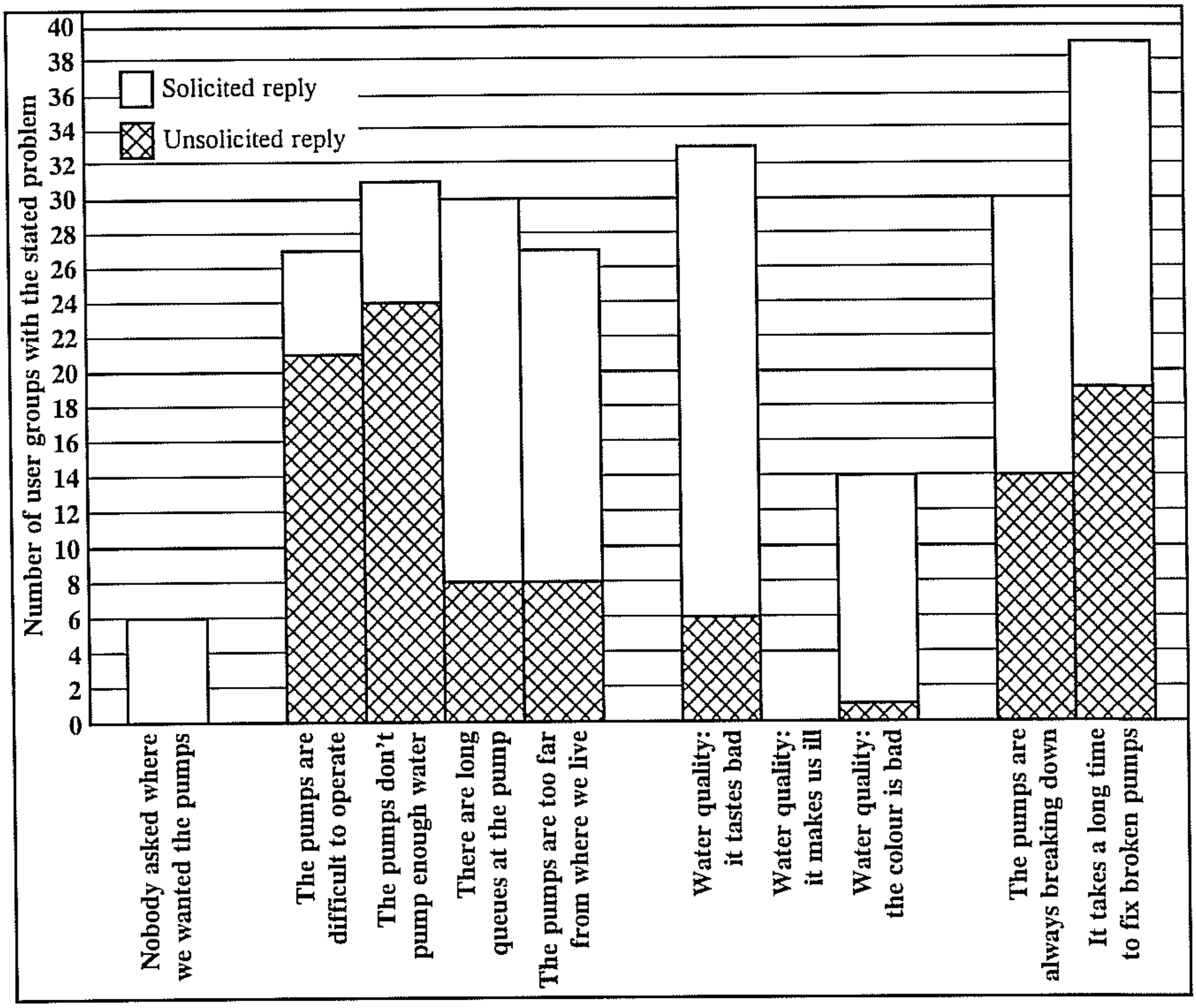


Figure 4.6: Problems users have with handpump installations

In Section 2.3 of the questionnaire, users were also asked to state which was the bigger problem: spending too much time collecting water because of pumps being too far away, or the fact that the pumps were often broken down. The split was almost even. In addition some respondents were unwilling to choose one of these, since they regarded both as a serious problem. Moreover, they interpreted the question of time in terms of queueing, as well as distance.

Finally they were asked to identify the biggest single problem of all. Unreliability, low delivery rate, and time spent, in that order, all emerged as major problems, as shown in Figure 4.7. Indeed most users made it clear that for an effective service all three problems had to be solved. A synthesis of comments made would read as follows: **"Improve the delivery rate of the pumps; this includes good preventative maintenance. Make the pumps more reliable. Above all shorten the time for repairs. Put in more pumps closer to our houses; this will cut down the walking and queueing times; and will also reduce the number of breakdowns, because the pumps will not have to work so hard."**

4.4.6 Attitudes to handpumps

In answering the remaining questions in Section 2, users made it clear that they appreciated the handpumps in their villages (when they worked). The alternatives, buying water from vendors, using unsafe water from rivers, relying on springs that dried up every winter, and digging in river beds in search of clean water, all gave the users an appreciation of the benefits of village handpumps. As well as using them for domestic water supplies, the majority of communities use their handpumps for at least one other purpose: livestock watering 47%, community gardens 33% and building 13%. This indicates the importance of ensuring the effectiveness of handpump systems until they are upgraded to a higher level of service.

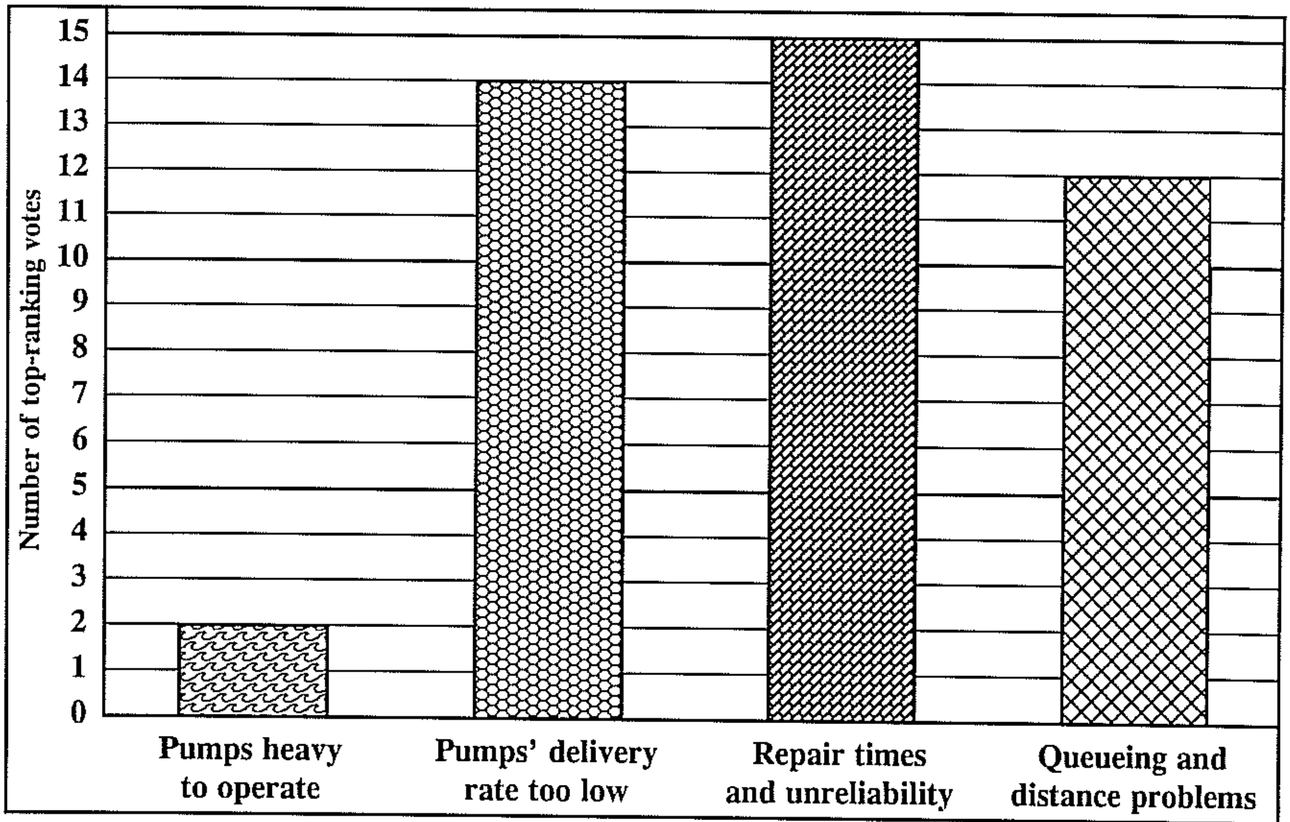


Figure 4.7: Handpump users' survey: ranking of four common problems by user groups

However, this appreciation should not be confused with satisfaction. Varying levels of dissatisfaction and unrealistic demands will still be the norm unless users understand the costs associated with other options and see tariffs corresponding to these costs being introduced systematically throughout their region. In addition some communities fear that making handpump systems more effective will jeopardise their hopes of obtaining a higher level of service later. All communities want to know that they are being heard with consideration rather than sensing that the top-down approach still reigns supreme and that the government is not committed to its development strategy for rural areas (GNU, 1994).

4.4.7 How pumps are cared for

Nine of the fifteen villages reported that there were no specific people in the village tasked with caring for the handpumps. In the six villages with nominated caretakers, not a single caretaker had any special tools for his job. One used his own tools and one used wire and pliers. The rest had no tools at all. The one with his own tools greased the bearings of the pump regularly and even got spares "from the government" to fix above-ground components when they broke. The one with wire and pliers "tried to fix things when they broke". Otherwise caretakers reported broken pumps to the chief or to a government official, but did nothing to care for the pump themselves.

Ten villages reported that no-one ever came to check the pumps between breakdowns. In the other cases it appears that government officials merely pass by to check for pump breakdowns but do not do any maintenance work. Not a single village reported carrying spares and when a breakdown occurs in an above-ground component they may try to make their own spares or buy something in the nearest town to fix it temporarily until somebody comes from government to do a better job.

The one village which had its first handpump installed recently reported that all users are responsible for the handpump. They take care to ensure that children do not treat the pump roughly and have built a fence to keep animals away. They also reported that cattle were taken to the river so that they would not need water from the handpump.

Overall however, little village-level caretaking or preventative maintenance takes place. Stated reasons are a lack of tools and spares. Other reasons are likely to include a lack of training, clearly defined responsibilities, motivation and remuneration.

4.4.8 Pump breakdowns and repairs

A third of the villages said that they owned their handpumps and an even greater percentage indicated that they had a responsibility to care for them. However, with respect to the breakdowns all the villages indicated some government involvement in the repairs and seemed to regard repairs as a government responsibility. Thus even when a pump supplier or another private company carried out the repairs, breakdowns were normally reported to government and in 80% of villages respondents reported that the government paid for the repairs or that they did not know who paid.

All the villages know that the cause of breakdowns is:

- too many people having to use the pumps.

Most villages added other aggravating circumstances including the following:

- rough treatment by children, who continuously play with the pumps even when there is no demand for water,
- a lack of maintenance, including no greasing of the pump-stand bearings,
- a shortage of water in the holes or, as a user in one village said, "the pipe is too short and doesn't go into the water enough," and
- parts get rusty, especially connecting parts.

However, knowing the cause of breakdowns does not translate into knowing how to organise caretaking that will reduce the breakdowns, although it does indicate that there is already knowledge in the villages to build on. Worse, just over half the villages reported that when a breakdown does occur it takes over 3 months to repair. The full range of replies is shown in Figure 4.8. Half of the villages reporting the over 3 months repair period said that they could not think of any reason for it taking so long. Others said:

- "The repair people have no regard for those living in the rural areas."
- "The government doesn't care about us."
- "You tell us, there is no good reason."
- "We go all the way to the government office and there is nobody there to report the breakdown to."
- "The repair people stay too far away."

- "The repair people stay too far away and just reporting the breakdown takes too long."
- "The boss of the repair people stays even further away, so nobody is organised."
- "They have too many pumps to repair."

Whilst timeous reporting of the breakdown is obviously necessary for speedy repairs, the current caretakers, with their minimum level of training, do not appear to speed up the process. Despite villagers' comments on distance, closeness to repair depots does not shorten the repair times. Four villages said that they pay for repairs but, on average, these villages do not get better service. On the other hand, distinguishing factors in the villages where pumps were fixed within a month are as follows:

- women or the chief reported the breakdown,
- both villages reporting repairs within one week used a private contractor, who had to travel over 60 kms from Pietersburg, and
- the village reporting repairs within two weeks also used a private contractor.

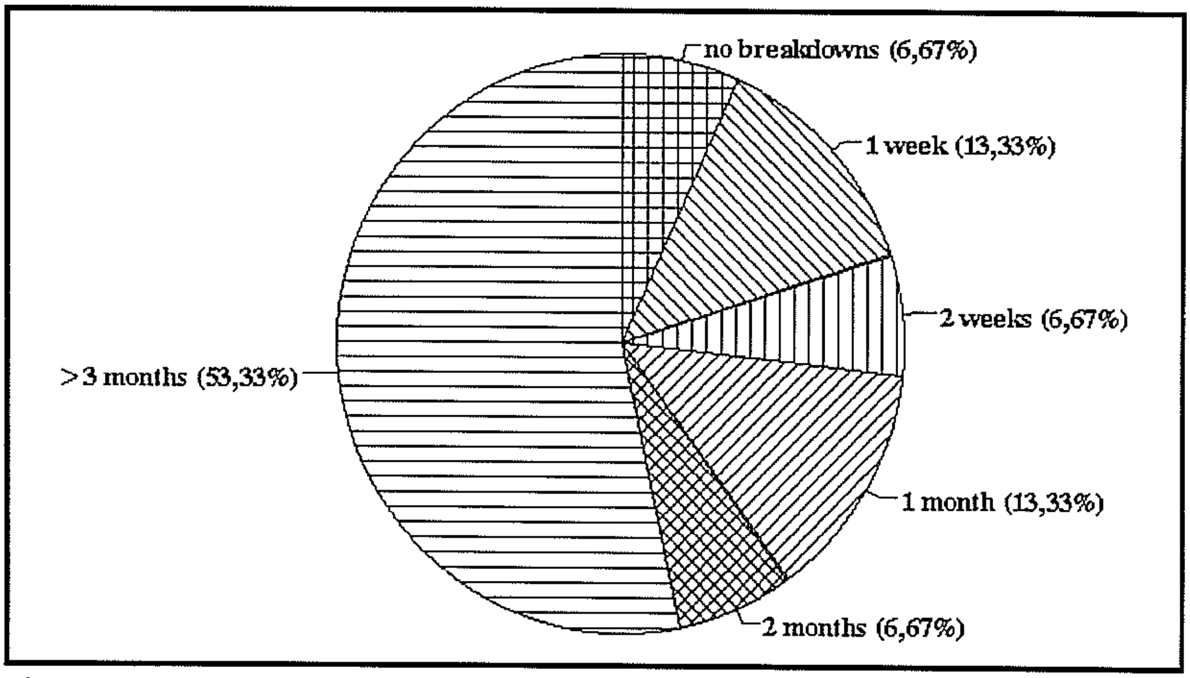


Figure 4.8: Handpump users' survey: reported breakdown repair times

4.4.9 Village structures and users' ideas on how systems can be improved

Seven of the fifteen villages visited do not have a water or a development committee. For the area being visited, the Southern District of Northern Province, this proportion is high and is an indication that villages which rely solely on handpumps tend to be isolated from development initiatives.

When users were asked if they had any ideas about how their handpump installations could be made better or more reliable, a variety of answers was obtained. The first set of comments recorded below have two objectives: giving the pumps less work to do so that they won't break down so frequently, and improving the level of service through customers not having to spend so much time and energy collecting water by having shorter queues and a pump closer to home:

- install additional pumps in our village (5 villages),
- install more pumps closer to the users,

- install better pumps closer to our houses,
- find some way of giving the pumps a rest.

These demands are worthy of serious consideration but without improved maintenance neither of these objectives will be achieved. This is because at present maintenance staff are often only motivated to repair broken pumps when a village reaches crisis point, i.e. after the last pump has failed.

The following comments generally indicate a well balanced attitude by community members; they are interested in assuming a fair share of the responsibility for pump care and maintenance but record that they will still need some long-term outside support and help:

- "New pumps which are easier to maintain should be installed."
- "We need lighter pumps which are easier to maintain."
- "We need to learn how to look after the pumps and how to fix them ourselves."
- "We need to know how to look after the pumps and how to test and check them ourselves."
- "Pump repairs must be improved" (2 villages).
- "We need one person in the village to be trained and made responsible for the pumps."
- "We need a good caretaker to look after the pumps."
- "We need better communication with people outside the village to improve conditions."
- "We need more government support."

The next two comments indicate that these villagers are not interested in caring for government property:

- "**They** must look after the pumps better."
- "As it is the government's pump they must come and sort the problems out without us paying."

However, both these groups of respondents indicated that they were interested in learning more about owning a VLOM handpump and how to care for it.

Lastly two villages were demanding a higher level of service than can be provided with handpumps.

- "Change the handpump to a motor-driven pump."
- "We want taps in the village."

These groups of respondents also indicated an interest in learning more about VLOM handpumps.

Finally communities were asked if they were interested in learning more about handpumps that are less difficult to fix, owning such a pump or pumps, how to care for handpumps, and organising cost recovery so that money is available to care for the pump. Generally answers were very positive. Only one village answered "no" to each of the four questions. This was the village that said it needed one person in the village trained and made fully responsible for the handpumps. Only one other village indicated that it did not wish to learn about cost recovery although they were interested in owning their own handpump and in understanding how to look after it. In three of the villages some respondents expressed doubts about having a pump that is easier to fix. There were fears that such a pump might be less strong or might deliver less water. All the other villages responded positively without hesitation to the four final questions.

5 PLANNED TEST-RIG EVALUATION OF HANDPUMPS

5.1 Introduction

This chapter discusses the planned test-rig evaluation of handpumps. As it turned out, no testing took place as part of this project, for the reasons given below. However, the description of the facility and recommended procedures for its use are included here for reference for possible future researchers.

5.2 Background to the test-rig evaluation of handpumps

The evaluation of handpumps in the field is problematic because of the difficulty of standardising test procedures and because of the lack of monitoring facilities. In addition, the CSIR's Building Technology Division possessed a handpump test-rig. In the project proposal submitted to the Water Research Commission by the CSIR it was therefore proposed to use this test-rig to augment the evaluations carried out in the various surveys.

The CSIR's test-rig uses a pressure sustaining valve to allow tests to be carried out at different pumping heads. Thus the actual length of riser pipe is only 10 m, or thereabouts, and higher heads are simulated by increasing the pressure at which the pressure sustaining valve opens. During the literature survey it became clear that for pumps using plastic riser pipes such testing gives worthless results at high pumping heads. This is because the plastic riser pipes can significantly reduce the discharge rate of deep well handpumps at high heads due to their flexibility. (Refer for example to Besselink, 1992, p. 9.)

When this was reported at the second steering committee meeting, Mr Adriaan van Niekerk, of the Agricultural Research Council (ARC), Silverton, Pretoria, offered to drill a 100 m deep 200 mm nominal borehole on their property, to seal it and to allow this project to use it to test pumps. Before the offer was accepted, the author contacted Mr Scott Devereux of the Consumers' Association Testing and Research (CATR) laboratories, Hertfordshire, England, to check the relative merits of testing pumps in a rig which simulates increased pumping heads and using a sealed borehole as offered by the Agriculture Research Council.

CATR was responsible for the laboratory testing of handpumps for the joint United Nations Development Programme/World Bank project for the field and laboratory testing and the technological development of rural water supply handpumps. (A summary of the results of the five-year project is published in Arlosoroff *et al.*, 1987, pp. 97-191.) Although the Association's promotional literature shows that they have a 50 m deep sealed borehole for testing pumps, these tests were carried out using a multi-pump test-rig similar to the CSIR's single-pump test-rig.

On being contacted, Mr Devereux reported that there was no comparison between test-rig testing and borehole testing but that time constraints and, to a lesser extent, cost had forced them to use a test-rig. Based on this information and the reports on the effects of the flexibility of plastic riser pipes, ARC's generous offer was accepted.

5.3 Preliminary commissioning of the test-rig

During 1995, on the third attempt ARC's contractors managed to drill a reasonably straight 100 m deep by 200 mm nominal borehole on their property, and more or less seal it. ARC also supplied and financed a flow measurement instrument, a water level monitoring device and the means of controlling the level of the water in the borehole. Concurrently, the CSIR's Division of Manufacturing and Aeronautical

Systems Technology (Aerotek) was commissioned by CSIR's Division of Water, Environment and Forestry Technology (Environmentek) to build a mechanical structure to connect a variable-speed electric motor to different types of handpump, namely direct-action-, lever- and wheel-actuated pumps, and to design and supply software and a loadcell to monitor all aspects of pump performance. A computer was also purchased and installed in a small Wendy house to store the data recorded during testing and to run the software for the pump performance calculations. All the above CSIR contributions were financed by the WRC.

As far as can be ascertained, the test facility is a world first, because of the depth of the test borehole and because the handpump can be driven by electric motor during performance testing. The former means that the effects of flexible rising main pipes can be tested under controlled conditions for the first time, and the latter provides for better repeatability during testing. Figures 5.1 and 5.2 give an indication of the improved repeatability achieved with a mechanically driven test-rig. Figure 5.1 is a typical load displacement diagram obtained from the human-operated test-rig used by the CATR laboratories. From this diagram one can see that the plot is a record of five complete pump cycles. Figure 5.2 is also a load displacement diagram but this time produced during preliminary commissioning tests on the electric-motor-driven test-rig constructed jointly by the CSIR and ARC. This second load displacement diagram is a record of two cycles, but because the test-rig is motor driven it is hardly possible to detect that two cycles have been recorded.

In the meantime, as soon as the contractors had completed the drilling, casing and sealing of the borehole, ARC began using it to test a deep well pump designed to be driven by a windmill, with their own test-rig and computer software. However, preliminary commissioning tests of the handpump test-rig and computer software were carried out in January 1996 using the ARC pump. These preliminary tests proved the test-rig's general suitability for the performance testing of handpumps. There was however some concern about the validity of the software package for calculating the power input and/or the calibration of some of the instrumentation because pump efficiencies in excess of 100% were being obtained for high head duties. It was discovered that the amplifier gain had been set assuming a maximum force of 300 N and thus the instrumentation software was unable to record forces in excess of this figure. As the pump being used for commissioning was designed for windmill use, input forces well in excess of 300 N were generated. After the gain had been reduced to allow for the acceptance of higher forces the efficiencies calculated were meaningful. However, it will still be necessary to ensure that the computer software is calculating the input power correctly, and to finalise calibration procedures for some of the instrumentation. It was planned to complete these tasks when ARC had finished its testing of windmill pumps.

The test-rig was also built with the thought that it could be used for accelerated endurance testing. For example the geared output of the variable speed drive allowed for output speeds of up to 120 rpm. The preliminary commissioning tests, however, suggest that operating piston handpumps above 60 rpm results in induced vibrations that bear little relation to the vibrations encountered at normal operating speeds of up to 40 or 60 rpm, depending on the pump and the pumping head. These vibrations at high rpm are likely to damage both the pump and the test-rig in less than two months. If the test-rig were to be used for endurance tests, these would therefore have to be carried out at speeds close to the pump's maximum design operating speed but no higher. **Thus the main use of the test-rig would be to carry out performance tests on handpumps in a sealed hole in which the water level can be varied at will.**

Possible future users should also be aware that during the early commissioning period a Pulsa pump was mounted on the hole. It immediately became evident that a motor drive does not reflect the rhythm that a human being naturally uses when operating such a pump. As a result the test was unsatisfactory. The same might apply, even if to a lesser degree, to other hydraulically operated pumps such as the Vergnet and the Barry.

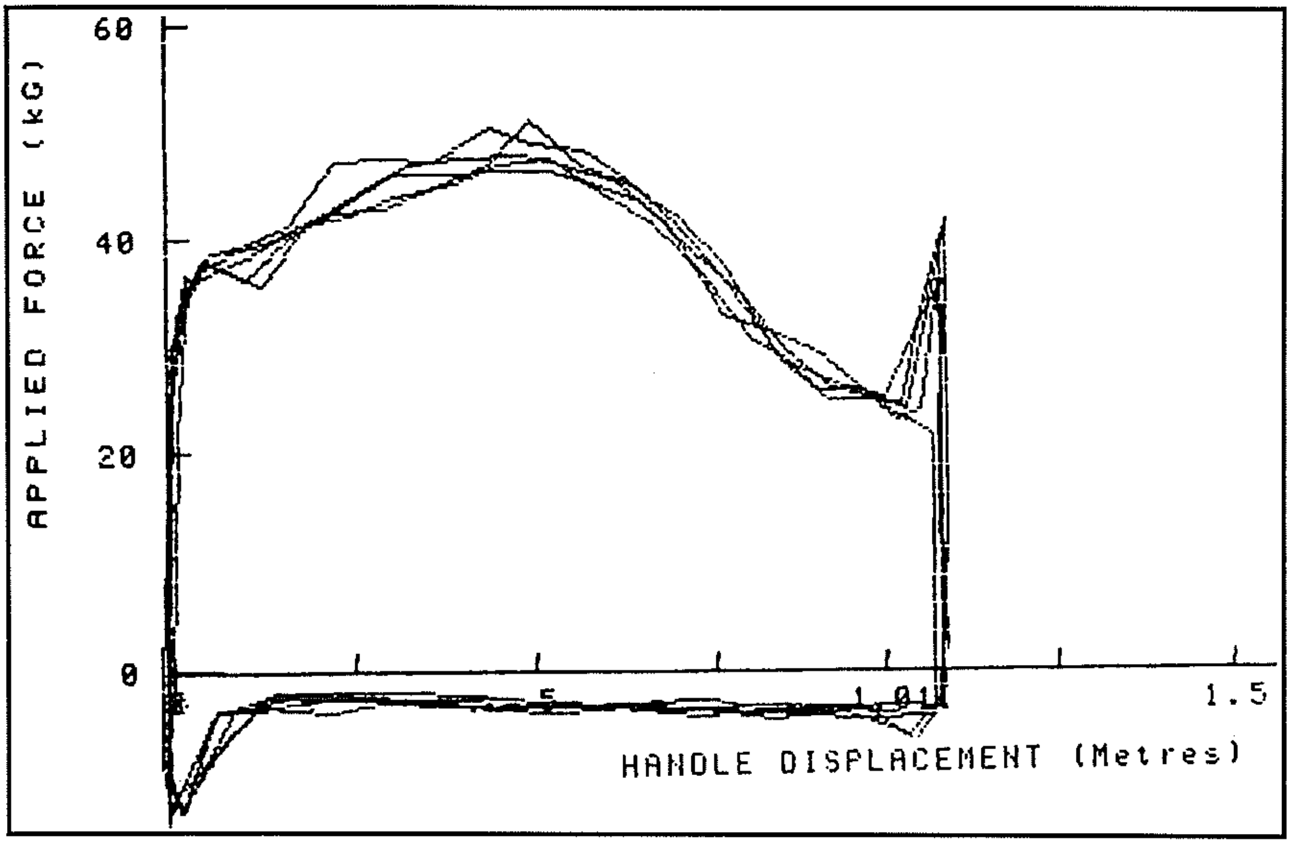


Figure 5.1: Typical load displacement diagram from the human-operated Consumers' Association Testing and Research test-rig in Hertfordshire, England (World Bank, 1984)

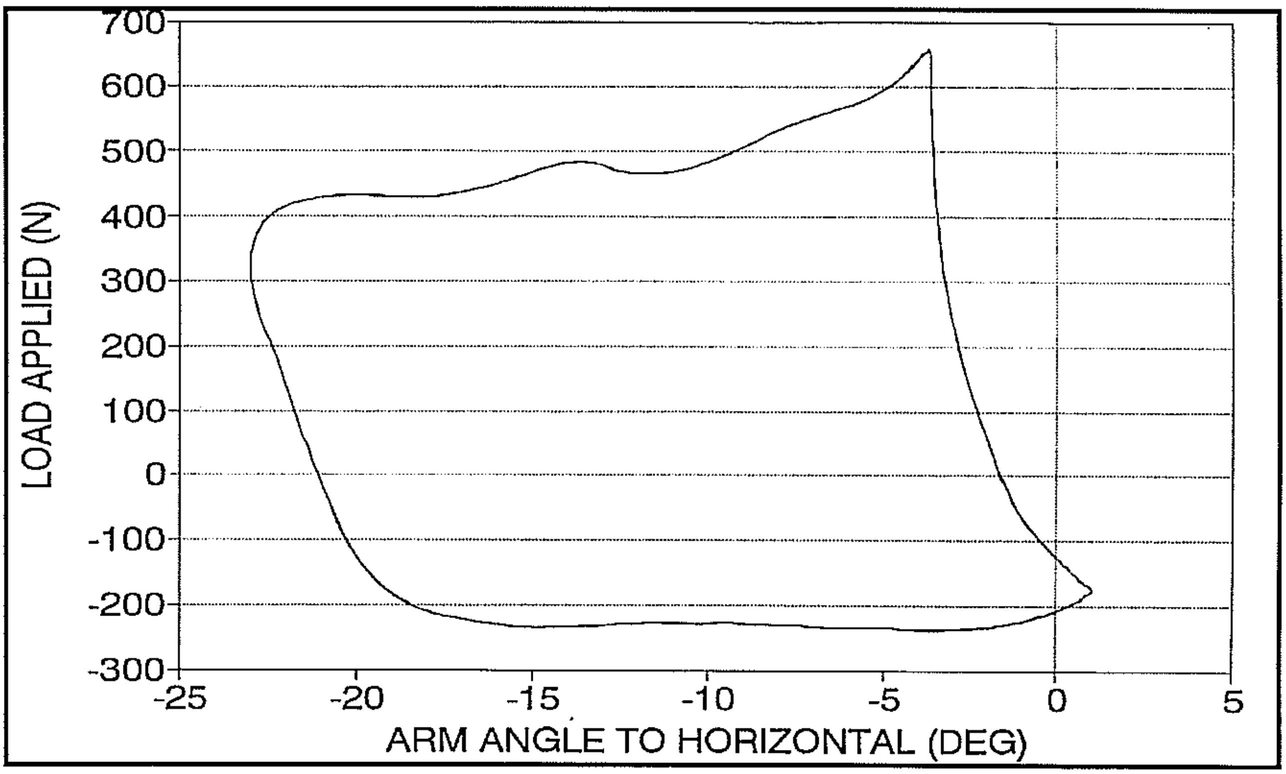


Figure 5.2: Load displacement diagram from the electric-motor-operated CSIR/ARC test-rig in Pretoria, South Africa, reflecting two cycles of a trial run

5.4 Why the test programme was abandoned

In October 1996, ARC made the borehole available to the CSIR to complete commissioning of the test-rig and to test its first handpump. In the interim VRM of the Netherlands had sent a modified prototype high-lift pump to their agents in South Africa for testing in the field. The agents and the CSIR agreed that it would be more useful to test the pump on the rig. Since it was a pump with a light weight GRP-screwed-and-socketed rising main, it was decided to use this pump for the first test. Problems with holding the riser pipe in place during installation and a disfunctionality between the length of the riser pipe and rod sections were quickly overcome, and two technicians were instructed to install the pump.

A safety rope was provided to be installed with the pump, to prevent the pump from falling down the hole in the event of a riser pipe failure. The technicians neglected to use the rope and after 15 x 3 m pipe lengths had been installed, the bonding of the sleeve on the top pipe failed and the pump cylinder with 15 lengths of pipe dropped down the hole. After three months of attempting to retrieve the pump from the hole, an outside borehole salvage contractor had to be called in to complete the task. By this time both money and time were running out and the Steering Committee agreed to exclude further commissioning of the test-rig from the project, particularly as cooperation was not forthcoming from Aerotek of the CSIR, who had been requested to assist with the provision of documentation on the computer software and the calibration of the loadcell.

5.5 Current status of the test-rig

This section describes the current status of the test-rig at ARC and describes outstanding tasks and recommended procedures for its use.

A submersible pump has been installed near the bottom of the borehole to make it easy to adjust the water level. The rising main of this pump, its power cable and a cable used for the water level pressure instrument can all get caught in the pump to be tested. To stop this from happening all these items have been encased in pipes installed on one side of the borehole. The resultant hole is satisfactory for testing pumps with rising mains which do not have to be constrained laterally in the borehole. As is, however, it is not satisfactory for testing pumps with a flexible rising main with rods that require constraining with centralisers, and a stiff secondary casing will need to be installed to accept the centralisers. ARC has already done the planning for the installation of a pipe of 5 mm wall thickness by 139,7 mm outside diameter, for this purpose.

The current status of instrument calibration procedures is as recorded in Table 5.1.

It is estimated that installing the secondary casing, finalising all the calibration procedures and carrying out a full set of performance tests on one pump would cost approximately R 130 000. Testing additional pumps would cost between R 45 000 and R 60 000 depending on whether a similar design of pump had or had not already been tested previously.

Obtaining pumps free of charge from South African pump manufacturers and importers for testing is not expected to be a problem, but until a full set of test results has been obtained and reported upon, they are unlikely to contribute any financial or manpower resources for the testing of existing models. Even thereafter contributions from this source are likely to be limited. On the other hand, carrying out full performance tests on handpumps in a deep borehole in which the level of the water can be varied at will would provide extremely useful information to pump purchasers worldwide, and it is possible that the WRC, or an international donor or development organisation such as UNICEF would be interested in providing funding for the first set of tests. Obtaining funding for further tests would depend on the quality of the results obtained and reported upon during the first set of tests.

Table 5.1: Current status of instrumentation calibration procedures

Instrumentation	Method of calibration	Procedure
A pressure sensor to measure the water level in the borehole	Check minimum and maximum settings. Intermediate readings are inherently linear.	Finalised
A flow meter to measure the handpump's flow rate	Volumetric	Finalised
A shaft encoder fitted to the test-rig's drive motor to monitor the handpump's speed and the position of the handpump's actuator in its operational cycle	Speed: Measure time for a fixed number of cycles with a stop watch.	Finalised
	Handpump's actuator position: Check bottom position of stroke from the sharp drop in force applied and any drift from the accuracy of the cycle overlays.	Conceptualised
A loadcell fitted to the pump actuator to measure the useful force required to operate the handpump	The loadcell itself: Weights	Conceptualised
	Setting the loadcell gain: Computer software sub routine	Required
A computer to store measured data and run software to calculate the input power, mechanical efficiency and volumetric efficiency of the handpump being tested	Check descriptive logic of programme and subsequent programming. (Descriptive logic not currently available)	Required

5.6 Outline handpump test specification

The following is an outline draft specification for the performance testing of handpumps, using the test-rig erected on a sealed borehole at ARC's property in Silverton, Pretoria.

5.6.1 A brief description of each handpump is to be written before the pump is tested. The description of the pump is to include the following:

- details of the pump manufacturer and the South African agents, if applicable,
- name, model number, type (e.g.: progressive cavity, single acting piston) and operating mechanism (e.g.: direct action, lever, handwheel),
- useful working head range stated by the manufacturer,
- minimum acceptable internal borehole diameter,
- cylinder area and length, and
- mechanical advantage of the operating mechanism.

This description is to be followed by an evaluation of:

- packaging, installation and maintenance instructions, and any tools supplied with the pump,
- any VLOM characteristics or other characteristics which make the pump especially suitable for the range of duties specified by the manufacturer,
- materials of construction with special reference to corrosion and abrasion resistance, as well as the availability of alternative materials,

- availability of local back-up services and spares,
- price of the pump cylinder, the pumpstand and each 3 m length of connecting materials, and
- current and potential availability of materials and facilities to manufacture the pump locally.

5.6.2 The following information needs to be recorded for each set of test points:

- time and date of the set of tests,
- length of rising main installed,
- drive stroke length, % of maximum design stroke length and length of lever arm (all as applicable),
- mechanical advantage of the drive mechanism, and
- details of any additional weights placed on the operating arm.

5.6.3 The following information needs to be recorded for each test point:

- static head, flow rate and number of cycles per minute, and
- plot of applied force against the pump operating mechanism position.

5.6.4 From the information recorded in Sections 5.6.1 to 5.6.3 the following parameters are to be calculated by the computer software:

- input power, output power, mechanical efficiency % and volumetric efficiency %.

5.6.5 The calibration of the test-rig is to be repeated at least three times during the testing of each pump. If any measuring instrument is found to have an error of more than 2 %, all tests carried out since the previous calibration are to be discarded.

5.6.6 As far as practical, performance testing is to be based on the following sets of test points listed in Table 5.2.

Table 5.2: Test points for performance testing of handpumps at different static heads

Head m	**Flow rates ℓ/min**						
** 6*	*15,40*	*20.53*	*25,67*	*30,80*	*35,93*	*41,07*	*46,20*
7	14,70	19,60	24,50	29,40	34,30	39,20	44,10
** 8,5*	*13,67*	*18,23*	*22,79*	*27.35*	*31,91*	*36,47*	*41,03*
**10*	*12,86*	*17,15*	*21,43*	*25,72*	*30,01*	*34,29*	*38,58*
12	11,88	15,83	19,79	23,75	27,71	31,67	35,63
18	9,85	13,13	16,42	19,70	22,98	26,27	29,55
25	8,03	10,70	13,38	16,05	18,73	21,40	24,08
35	6,28	8,37	10,47	12,56	14,65	16,75	18,84
45	5,17	6,89	8,61	10,33	12,05	13,77	15,50
55	4,37	5,83	7,28	8,74	10,20	11,65	13,11
65	3,78	5,03	6,29	7,55	8,81	10,07	11,33
80	3,10	4,13	5,17	6,20	7,23	8,27	9,30
95	2,57	3,43	4,28	5,14	6,00	6,85	7,71

* *These sets of test points are only to be used for shallow well handpumps.*

Except as detailed in Section 5.6.7, all tests are to be carried out with the pumps operating at full stroke. This is to be achieved by changing the speed of the pump.

The flow rates in the middle column of Table 5.2 have been set equal to the minimum acceptable flow rates for handpumps operated by one person, as shown in Figure 6.1. The flow rates in the final column have been set 50 % higher than the flow rates in the middle column. The flow rates in the other columns have been set equally spaced in each row, the spacing for each row being primarily dependent on the value of the minimum acceptable flow rate entered in the middle column.

If it is not possible to test a pump over the full range of flows specified for each head, every effort is to be made to test at least up to the flow rates shown in the middle column. In addition at least five well-spaced flow-rate test points are to be selected for each head setting.

When testing pumps that have been designed to be operated by two people, additional test points with flow rates in excess of the flow rates in the last column are to be evaluated, if such flow rates can be achieved without operating the pump at speeds in excess of 60 cycles per minute.

During testing, any signs of abnormal vibration are to be noted and reported, and checks are to be made to ascertain if the vibration originates from the pump or from the test-rig.

5.6.7 When a minimum acceptable flow rate is achieved with a lever-operated pump at a speed of less than 60 cycles per minute, an additional test point is to be set up and evaluated by setting the speed at 60 cycles per minute and reducing the stroke of the pump until the flow rate equals the minimum acceptable flow rate at that head.

Special cases of stroke reduction exist when it is possible to vary the stroke of a wheel- or lever-operated pump, by varying the distance between the drive mechanism's main bearing housing and the point where the pumprods are attached to the drive mechanism. With such pumps additional sets of tests are to be carried out when it is possible to reduce the stroke and still obtain the minimum acceptable flow rate at 60 cycles per minute or less.

For progressive cavity pumps, varying the gearbox ratio has a similar effect, but the resultant changes in performance are easy to calculate. For these pumps therefore, additional tests with different gearbox ratios are to be decided on in consultation with the pump supplier, keeping in mind the 60 cycles per minute versus minimum acceptable flow rate concept stated above.

5.6.8 Each pump is to be installed with rising main lengths of 15, 30, 48, 66 and 96 m, subject to compatibility with the pump's maximum working depth. At each depth setting, the pump is to be tested over the full range of applicable heads or over the five highest applicable heads, whichever results in the fewer number of applicable heads to be tested. The possible performance tests are then to be repeated reversing the lengths of rising main installed, starting with the maximum length and back through 66, 48, 30, 15 m.

5.6.9 Pumps with riser mains that are to be fitted with centralisers are a special case. For installation depths up to 30 m the supplier's instructions are to be followed. For installation depths of 48 m and above additional tests are to be carried out with 1, 2, 3, etc. centralisers fitted per 3 m length of riser main, until no improvement in performance is observed.

5.6.10 Graphs of flow against cycles per minute, input power, peak force, mechanical efficiency % and volumetric efficiency % are to be plotted for the full-stroke set of points obtained at each head setting. The effects of changing the stroke to the minimum acceptable flow rate for each head are also to be indicated on these graphs, as applicable.

Ways of plotting flow rate versus head curves for different parameters such as constant input power or limiting human capabilities are also to be investigated.

6 DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

6.1 Overview of the world situation

From the survey of purchasers and, to a lesser extent, the literature survey, it is clear that the environment in which handpumps are installed and maintained varies substantially from country to country. This environment has a major bearing on the effectiveness of the installations and the longer term development of the local communities. Below are typical scenarios of what is happening around the world. No countries' names are given because the scenarios are simplified pictures and therefore do not reflect accurately the position in any one country. However, it is hoped that the elements of the different pictures will help readers to reflect on their attitudes and the environment in which they are working and that, through critical reflection, handpump installations can become more effective and their use targeted appropriately.

a) The work of a multiplicity of foreign donors and foreign aid workers predominates. Handpumps play an important role in bringing improved water supplies to many communities, but often the handpumps promoted are not the most suitable for the area and there are too many different types, which complicates spares procurement. In addition, the foreign aid workers do not transfer sufficient authority or skills to the local people. As a result, although the current quality of service provided by the handpumps is acceptable, the longer term sustainability after the foreign aid workers leave is in doubt.

b) National influence is strong. The policy leadership comes mainly from young, first-generation professionals. These professionals and even local government officials have a negative attitude towards handpumps and are not prepared to support such technology enthusiastically, even though, in the short to medium term, it is the only feasible option for improving the water services to many rural villages. The handpumps that do get installed are not maintained. The professionals are enthusiastic about constructing new regional water supply schemes, which improve the water delivery to many villages. However, other villages in crisis fall outside the regional schemes and the gap between the best- and worst-served widens. Even worse, in some countries, the sustainability of these regional schemes is in grave doubt.

c) National influence is strong but the policy leadership comes mainly from older professionals of immigrant stock or from powerful local families. Effective handpump installations are the norm but these professionals frustrate the legitimate aspirations for higher levels of service from many villages.

d) National influence is strong. The policy leadership comes from older professionals who have developed a true empathy with the aspirations of the poorer rural and urban communities. Foreign donors and foreign aid workers are active in these countries but their work is managed in terms of broad national objectives. Effective handpump installations play an important role in domestic and livestock water delivery. The refurbishment and maintenance of existing schemes to high standards has as high a priority as building new schemes. Moreover, slowly the scene changes as higher level of service stand-alone village and regional water schemes are built and maintained in conformity to challenging quality standards and in accordance with transparent national and local affordability criteria. The new schemes are used to provide water for irrigation and small local industries as well as higher levels of service for domestic use and livestock watering. In the meantime extension officers are still monitoring the handpump installations and supporting village-level structures where necessary to ensure proper maintenance and cost recovery.

6.2 Major project findings and recommendations

The consolidated findings from the literature survey, the analysis of South African borehole and handpump installation records and the surveys of handpump stakeholders indicate that three broad areas of project implementation have to be carried out competently to achieve effective community handpump systems. The three broad areas are:

- development of the boreholes and measurement of recovery rates,
- selection and installation of the handpumps, and
- ensuring adequate village, local government and private enterprise institutional and skills capacity.

It is also important that the managers of installation and maintenance programmes have a positive attitude towards the use of handpumps for normal service delivery as well as for emergency relief supplies and that they can motivate other stakeholders to have a similar attitude, whilst being sensitive to user feedback.

6.2.1 Borehole development and measurement of recovery rates

The development of the borehole is an essential component of the implementation of effective community water supply programmes using handpumps. Moreover, when the cost of drilling unsuccessful holes is included, the development of the borehole can be expected to cost between 65 and 70 %of the total cost of the project. (The literature sometimes quotes a figure as high as 90 %, but in these cases insufficient resources will have been devoted to institutional capacity building and skills training.) The importance of the development of the borehole combined with its cost, emphasises the care that needs to be taken during this phase of project implementation.

Having completed the necessary feasibility study and confirmed or created community support for the installation of handpumps, one of the first decisions to be made is where to drill the boreholes. The services of a competent hydrologist should be secured, and he/she should discuss with the community where holes are to be drilled, and select the positions with them.

Once water is struck, its quality should be checked to see if it is fit for purpose with respect to health, taste and colour. An overview of the causes of poor quality groundwater and how it is sometimes possible for communities or households to treat the water cost-effectively is given in Section 2.3.

As referred to in Section 2.5, borehole development, in the sense of enhancement, which most commonly entails removing fine materials from the formation zone close to the borehole wall, can sometimes significantly increase the water flow-rate into the borehole and/or improve a borehole's life by reducing future clogging. Should the geological conditions, local experience or the conditions encountered whilst drilling or examining the blow yield water indicate that enhancement of the borehole by such techniques as intermittent pumping and backwashing or surging would be beneficial, it should be carried out.

Because of the small quantities of water pumped, handpumps seldom have any measurable effect on the long-term static water level in boreholes. Handpumps are however frequently placed on marginal boreholes in which the water level drops dramatically whilst pumping is taking place until the water flowing into the borehole matches the water being pumped out. This can even happen in boreholes which have been skilfully developed. Before one can select a suitable handpump and the depth at which the pump cylinder is to be installed, it is therefore essential to do a short duration constant pumping rate test, at a rate in excess of that which can be achieved with a handpump, followed by a full borehole recovery-from-drawdown test. Two simulated test results are shown graphically in Figures 3.6 and 3.8.

If the borehole has been drilled in a fractured rock secondary aquifer and the recovery from the drawdown test reflects a permeability which is so low that even after lowering the water level close to the bottom of the borehole the rate at which the water is flowing into the hole is insufficient for its intended use (refer Figure 3.9), consider hydro-fracturing to increase the permeability of the borehole's formation zone. If hydro-fracturing is carried out, repeat the constant pumping rate test followed by the recovery test.

It is also important to check for indications that the water may be abrasive. As indicated in Section 2.2.7, by far the best way of managing abrasion is to prevent the abrasive particles entering the pump rather than buying a pump specifically designed to handle abrasive material. This must be done whilst the borehole is being developed. Whilst standard slotted borehole screens are ineffective, gravel packed screens, if correctly designed and installed, overcome the problem completely. Such screens can be bought with the gravel already bonded to the screen or they can be developed by filling the cavity between a temporary outer casing and the permanent casing/screen *in situ* with a suitable gravel. Suitable gravels are of a fixed size, structurally and chemically stable, and non-corrodible. Typical grain sizes vary from 1 to 3 mm, whilst the difference in diameter between the outside diameter of the permanent casing/screen and the inside diameter of the temporary casing, to allow for the gravel pack, should not be less than 75 mm.

Check from local knowledge and tests for indications that the water may be corrosive. As reported in Section 2.2.6, galvanised iron casings offer little or no protection against corrosion. On the other hand, even where structural failures caused by corrosion are unusual, low intensity corrosion causes the quality of water being handpumped from a borehole to deteriorate because of the corrosion causing zinc and iron contamination. The contamination caused by the wrong choice of borehole casing material is likely to have a greater effect on the deterioration of the water quality than the wrong choice of material for the pump rising main, especially with respect to how much water has to be pumped each morning before it returns to an acceptable quality. If in doubt, therefore, choose a non-corrodible material such as uPVC for casing the borehole. Additional comments on the zinc and iron concentrations that cause unacceptable water quality are given in Section 2.3.4.

6.2.2 Selection and installation of suitable handpumps

Check pump make and type preferences with future customers. The handpump users' survey and to a lesser extent the purchasers' survey indicate that users prefer lever-operated piston pumps to wheel-operated piston pumps and rotary screw pumps. For low heads, up to about 12 m lift, indications are that direct action pumps may be preferred. The users' survey also makes it clear that users prefer a high delivery rate pump to one that is "easy to use". That is, a short tough task is preferred, with the proviso that children must be able to pump something. Thus, although foot-operated pumps were not covered by either the pump users' or purchasers' surveys, it is likely that for lifts in excess of 60 m users would favour a pump designed for foot operation by two people. Figure 6.1 (an adaption of Arlosoroff *et al.*, 1987, box 5.1, p. 73) can be used to decide the minimum acceptable discharge rates for different total lifts. However, even if the project implementor thinks he/she knows what will work best, it is important to understand that users often have important local knowledge and that they want to know that they are being heard with consideration. If users sense that they are being ignored and that a top-down approach reigns supreme, they are likely to reject all forms of cost recovery after commissioning and perhaps even the handpump itself.

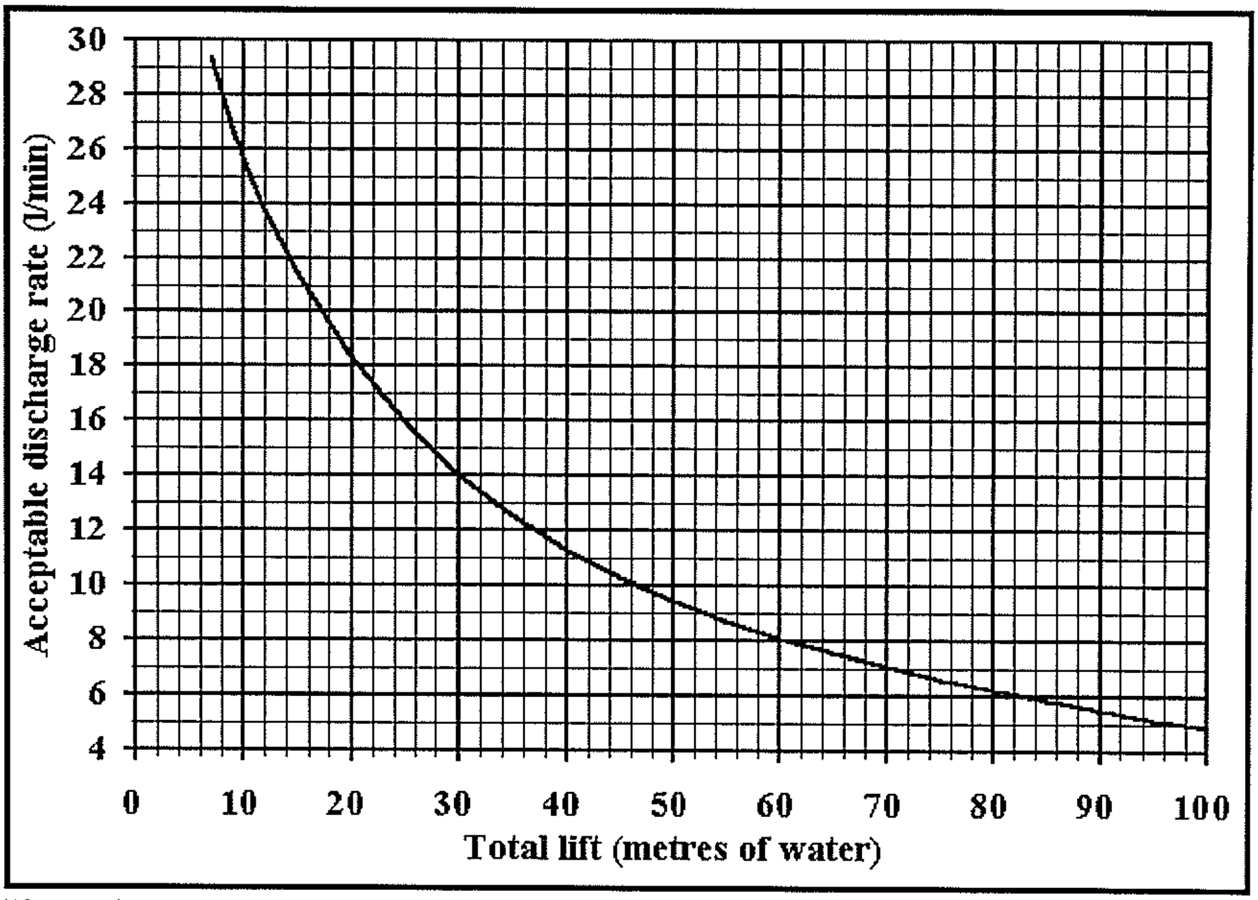
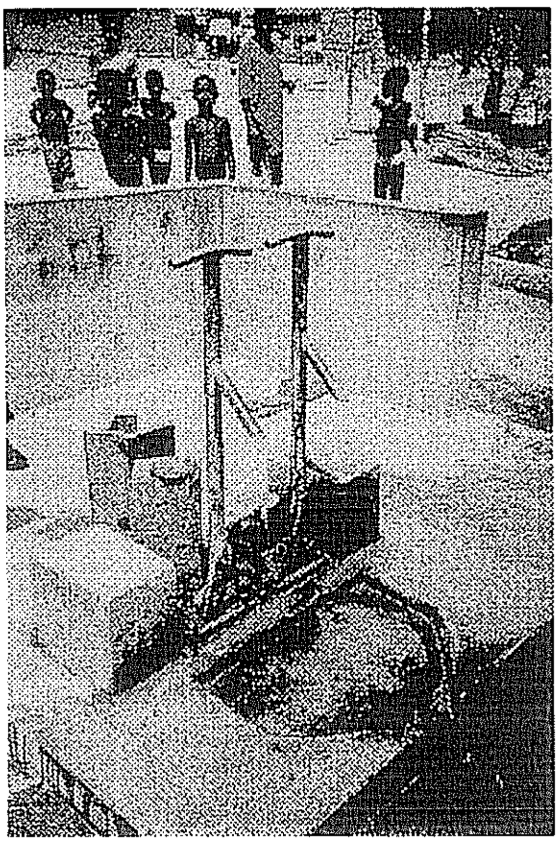


Figure 6.1: Handpump characteristics: acceptable discharge rates versus total lift

Before deciding on the borehole casing, checks will have been made for indications that the water may be corrosive. Section 3.6 of this report indicates that in South Africa up to 40% of boreholes contain corrosive water, which makes the use of galvanised iron components unsuitable for handpumps. Water with concentrations of iron above 1,5 mg/ℓ has a bad taste and a reddish colour. In turn this water stains laundry and even changes the taste and colour of food cooked in it, making users reluctant to accept such water and encouraging them to abandon the borehole altogether. Water with a zinc concentration above 4 mg/ℓ is also likely to be rejected by potential users. The problem is much more severe with handpumps than with motorised pumps because of the low daily output from the handpump. The very rapid fall-off in the contaminants shown in Figures 2.8 and 2.9 suggests that it is only necessary to pump out the water already in the pump's rising main to get good quality water once again after pumping is resumed in the morning. Langenegger (1988, p. 5) however reports that contamination of the rest of the water in the borehole from the outside surface of the pump's rising main (without contamination from the borehole casing material?) falls off much less rapidly, with iron concentrations still being unacceptably high after twice the storage capacity of the borehole has been pumped. Therefore, as with the borehole casing material, if in doubt, take corrosion into account when selecting a suitable pump.

During the development of the hole, a full borehole recovery-from-drawdown test will have been carried out. Use this test as indicated in Figures 3.7 and 3.9 to help decide at what depth to install the pump, what type of handpump to recommend to the community and how many people it can serve effectively. Augment the results of the recovery test with local and recorded knowledge about seasonal and longer term variations in the static water level. Then use the instructions set out in the last page of Box 6.2 to refine the decision with respect to the depth at which the pump cylinder is to be located.

The literature survey has shown that VLOM pumps and standardisation are both important tools in the quest for effective service delivery. Thus, if the demographic area in which the pump is to be installed has already standardised on a VLOM pump which satisfies the criteria described in the preceding paragraphs and those given in Box 6.3, it is strongly recommended that this pump be purchased. If not, write or obtain a specification covering all the criteria and buy a suitable VLOM pump that matches the specification. Insist that the pump supplier also supplies a comprehensive installation and maintenance manual. Section 3.5.2 postulates that in South Africa there is a large drawdown of the water level in a significant percentage of boreholes whilst handpumping is taking place. It is therefore expected that the percentage of handpumps in South Africa falling into the extra-high-lift application category is in excess of 20%. Currently, well designed foot-operated hydraulically driven pumps with HDPE riser mains appear to be the best proven VLOM design for heads in excess of 40 m for both corrosive and non-corrosive environments. There are thus strong indications that, in South Africa and Mozambique at least, purchasers should be paying more attention to the effectiveness of such HDPE rising main pumps to cope with high head duties. In some areas, it may even be advantageous to standardise on such a pump type for all duties. These comments do not preclude the possibility of achieving effectiveness through the use of other types of VLOM pumps.



Having decided on a suitable pump to purchase, select a suitable pump platform to cater for all the ergonometric and hygiene needs of future customers. Box 6.4 gives more details of these needs and also discusses the possible need to fence off the area to protect the aquifer from contamination due to the presence of livestock. Once the platform has been built and allowed to cure for at least seven days the pump can be installed. To enable the yield and water level of the borehole to be monitored whilst pumping is taking place, provision should be made to allow for the level of the water in the borehole to be measured without removing the pump. To prevent contamination of the water in the borehole, the level measuring area must normally be sealed off.

Figure 6.2: Recently installed Vergnet foot-operated pumps with the water container area slightly sunken to stop contaminated water finding its way back into the borehole

6.2.3 Institutional requirements

From a South African viewpoint, a disturbing outcome of this study was the divergence between South African and "rest of the world" community water professionals as to their confidence in the ability of handpumps to provide an effective service. This bodes ill for a sustainable service since it is essential that implementing agents and local authorities have a positive attitude towards handpumps. Can the scenario in 6.1 d) become a reality everywhere?

How do South African communities themselves regard handpumps? As detailed in Section 4.4.6, the answer is: not as negatively as the professionals who answered the purchasers' survey. Communities appreciate their handpumps and know that with better project implementation and maintenance these handpumps would deliver a better service. However, in the present climate of high expectations and few rural communities paying for water, the demand for individual yard connections is high. An additional major threat to the wider acceptance of handpumps is the fear that more effective handpump systems will jeopardise communities' hopes of obtaining a higher level of service in future.

Thus, the first institutional requirement is that handpump projects are implemented, monitored and supported by agents who believe in such projects, but who also understand communities' aspirations for higher levels of service. A more equitable external environment, where all who can afford it are paying for water at a price more closely related to the level of service and the cost of provision, and where indigent households all receive the same monthly subsidy, is likely to raise the demand for handpumps substantially. Acceptance will also be enhanced by ensuring that future customers are involved in each of the following steps of the decision-making process:

- What sort of institutional arrangements will be set up in the village to manage the water supply and cost recovery arrangements?
- How will this village-level institution interact with its local water authority?
- How will water be delivered to the village?
- What type and make of handpump or footpump will be utilised?
- How many pumps will there be? (The daily demand from each pump should be supplied in five hours.)
- Where will they be placed?
- What facilities are to be incorporated in or around the pump platform (laundry facilities, livestock watering)?
- Who will be trained to care for the handpump installations?
- How will customers pay for the service?
- Will poor families pay less?
- What will the money be collected for?
- How will effectiveness, accountability and transparency be achieved?
- Who will be responsible for major repairs?
- Who will be responsible for ensuring that spares are available when needed?
- How can the improved water supply scheme be used to improve the health of community members?

The above list makes it clear that the institutional requirements for the long-term sustainability of handpump water supply schemes are similar to those required for any other community water supply scheme. Thus, from the outset facilitators must evaluate the gap between a community's current institutional capacity and the capacity required to manage, maintain and sustain the infrastructure on completion. There is no better way of doing this than ensuring that a well-trained and motivated inclusive village-level committee is operating before any boreholes are drilled or pumps selected. An inclusive committee will include elected men, women and youth plus *ex officio* tribal and local authority representatives, all of whom take part in the discussions when the committee meets. A well-trained committee with suitable leadership will not make decisions without involving the rest of the community.

Various studies have verified that the best-maintained, cost-effectively operated community water schemes are managed by the communities themselves. However, these communities still need to know that they are not on their own but part of something bigger (Hodgkin *et al.*, 1994, p. 12). Thus, ideally they should be audited and supported by an extension officer from their responsible local, district or regional councils about four times a year or more frequently if necessary. If the local council does not have the capacity to fulfil this role a local NGO or consultant should be appointed to carry out the task, with the additional responsibility of looking out for exceptional talent which can be promoted to higher level government structures.

Currently in the rural and peri-urban areas of South Africa, due to mistrust, there is a strong community feeling that any revenue collected in a village should stay there. Therefore, even in areas with good cost recovery, there are likely to be problems in finding funding for auditing/support work. However, since 1998 local councils have received an "equitable share" of the nationally raised taxes to help them with the operation and maintenance costs of basic services to households with an income of less than R 800 per month. They could use some of this subsidy for the auditing/support work described above but they are also expected to pass on at least some of the subsidy directly to the poor households (DCD, 1998). Doing this would also help to build up trust between village-level structures and local councils.

As well as institutional capacity there is the need to train people from the village to look after the day-to-day care of the handpumps and surroundings. More than one person should be trained to allow for helpers and for people leaving the village. It is often a good idea to appoint one person as the senior caretaker and to have an assistant living close to each handpump. Women often commit themselves to staying in the job longer than men and are more interested in keeping the area around the pumps clean as well as ensuring that the pumps function satisfactorily. Train and select the pump caretakers before the pumps are installed so that they can help with the installation and learn from practical experience. Ensure that they also learn how to carry out a borehole recovery test and that instruction manuals for monitoring the borehole and caring for the pumps are left in the village.

No water scheme will be sustainable without money being available for major repairs and for the spare parts to carry out the repairs. It is also easier for the village committee to motivate caretaking staff if they are paid for their work. As the work will be part-time and as most of the money will come from community members, the payment to caretakers should be modest and be decided by the villagers themselves. It is also common practice for caretakers to be responsible for collecting the payments and for their pay to be a percentage of the money collected, for as long as the pump is in good working order. Receipts must be issued for money collected and a book-keeper appointed. Again, if the selection and training of the book-keeper take place before project implementation the project costs can be routed through the village book-keeper, who gain hands-on experience while the maximum guidance is available. Assuming that the local council is topping up the village committee's finances, from the equitable share payment it receives from national government, these payments could be reduced by the ratio of the water committee's actual income to potential income from non-indigent households as a further incentive to collect all payments owing. All parties will also have to agree what percentage of the money collected can be used to pay the book-keeper, on presentation of the balanced accounts each month to the community, and what percentage is to be kept for other current expenses and major repairs.

To plan properly for sustainability, the water committee should have a constitution, it should have a contract with its local council to act as the water service(s) provider for the village, and the book-keeper and pump caretakers should have job descriptions which include details of how they will be paid. The pump supplier, the facilitating agent, the village water committee and the local council also need to agree on how major repairs are to be carried out and who will be keeping the spares. Lastly the implementation of water supply improvement projects creates an ideal climate in which to address water- and hygiene-related health issues. If the opportunity is missed the maximisation of benefits from a successfully implemented and managed scheme will be severely compromised. Do not let the opportunity pass.

6.3 Decision support and work-flow guidelines

The previous sub-sections discussed the broad areas which need to be carried out competently to develop effective community water supply systems using handpumps and footpumps. In the current section the requirements are rearranged chronologically in five boxes as flowcharts or guidelines to enable project implementors to follow the execution process step-by-step. The titles of the boxes are as follows:

- Box 6.1: Flowchart for initial community consultation and planning
- Box 6.2: Flowchart for borehole drilling, development and casing
- Box 6.3: Guidelines for the selection of VLOM human-powered pumps
- Box 6.4: Guidelines for the installation of human-powered pumps
- Box 6.5: Guidelines for setting up ongoing management procedures

Box 6.1: Flowchart for initial community consultation and planning

Are there any unsatisfied demands for water in the community, including demands not being met because of the poor operation and/or maintenance of the existing infrastructure or the unreliability or the poor quality of the water sources?

No → No action required.

↓ Yes

Are any plans already in the process of being implemented to satisfy these demands?

Yes → No action required.

↓ No

Have any plans been drawn up to satisfy these demands without any process for implementation being initiated?

Yes → Ensure that the existing plans are taken into account in future planning. ↓

↓ No ←

Are there local government and community-level institutions in the area with the capacity to play their delegated roles in project implementation and ongoing operations and maintenance management.

No → Evaluate the gap between the local institutions' current and required capacity to play their delegated roles. Ensure that plans are implemented at each stage to create the required financial, technical, and institutional capacity or to bring in temporary supporting capacity to effect a sustainable project. ↓

↓ Yes ←

Quantify the demands and classify them in terms of basic and high level human needs, animal watering, community gardens, general irrigation and industrial use. Prioritise the demands and check if some minimum interventions are required for crisis relief.

↓ *Continued overleaf*

Box 6.1 cont: Flowchart for initial community consultation and planning

↓ *continued from previous page*

Are there underutilised or wasted water resources or infrastructure in the area? It is especially important to check for wastage if meaningful cost recovery has not been implemented in the area. Include infrastructure in need of refurbishment.

No →

↓ Yes

Draw up an assets inventory, condition, usage and cost recovery history therefrom. Classify the current and potential "adequacy" rating of the existing infrastructure and currently available water sources.

↓

List possible water sources in the area and immediate vicinity that could be developed including: springs, groundwater, perennial (permanently flowing) streams or rivers, dam sites and nearby existing regional schemes with possible excess capacity.

Is there currently a deficit of good quality water available in the area?

Yes →

↓ No

↓

←

Prepare multi-solution, multi-service level feasibility study report giving budget capital costs, running costs and alternative methods of cost recovery.

↓

Workshop report with community through a representative village water committee or development forum to ensure that the community are behind the choice of upgrading project(s) and cost recovery option(s) and that they have agreed to the choice from a well-informed position.

↓

Facilitate up-front contributions from community members to ensure commitment to the selected options. For basic levels of domestic water supply this contribution can be deposited in a separate maintenance fund account controlled by the village water committee for use after project completion rather than being absorbed as a capital contribution (e.g. Mvula Trust, 1996b, p. 3.6).

↓

Seek grant and/or loan funding, as appropriate, to pay for the capital cost of the project. Ideally these funds should be channelled through the village water committee for their management, under the supervision of the funder, as is done on Mvula Trust funded projects (Mvula Trust, 1996a, p. 17).

↓

Do any of the selected projects make use of groundwater?

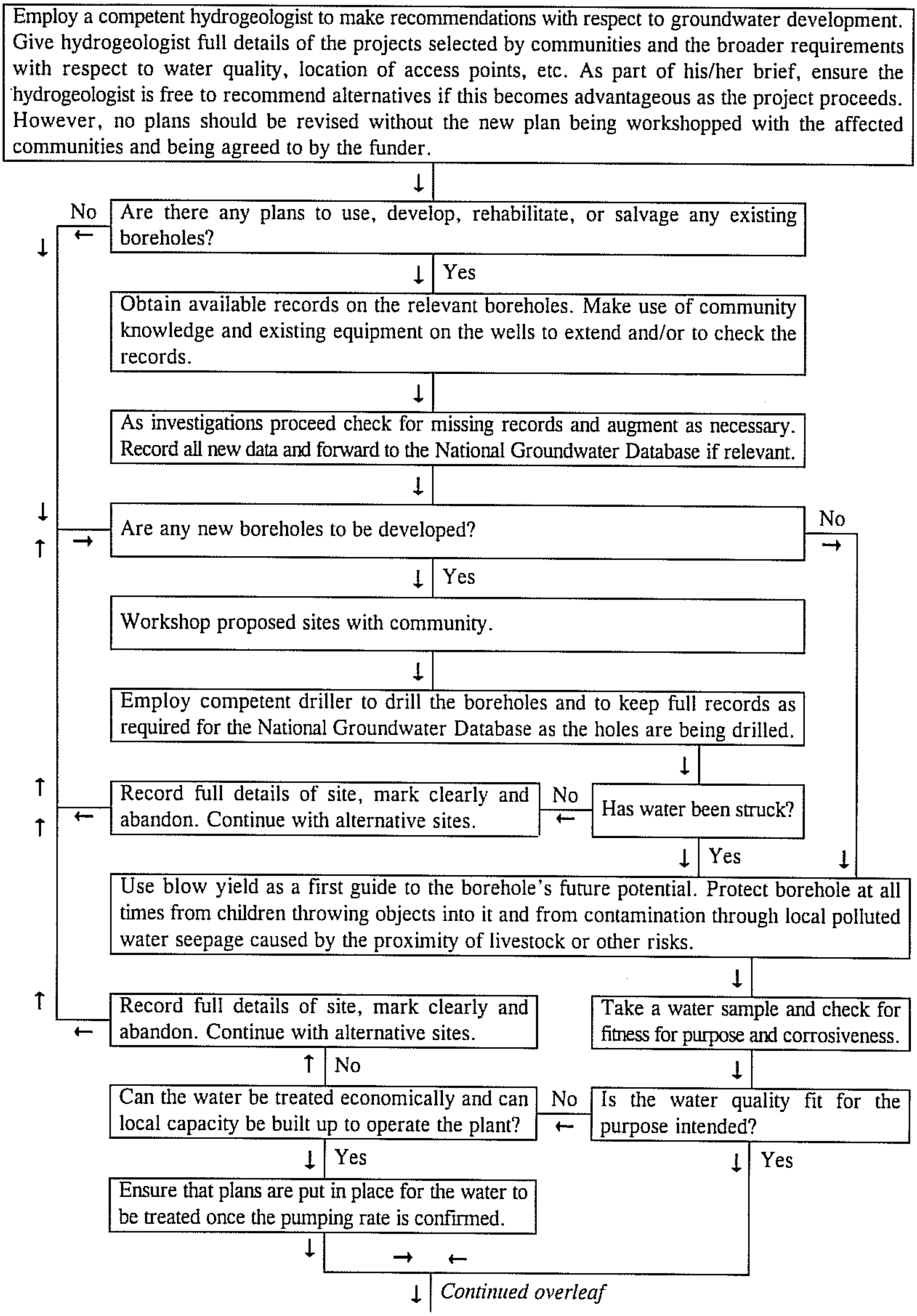
No →

For detailed decision-making on using water sources other than groundwater refer to more general literature on **community** water supply development.

↓ Yes

Proceed to Box 6.2.

Box 6.2: Flowchart for borehole drilling, development and casing



Box 6.2 cont: Flowchart for borehole drilling, development and casing

↓ *Continued from previous page*

Do the geological conditions, local experience or the conditions encountered whilst drilling or examining the blow yield water suggest that development of the borehole (by techniques such as over-pumping, intermittent pumping, backwashing or surging) would increase its recovery flow-rate, reduce sand ingress and/or improve its long-term recovery flow-rate by reducing future clogging?

↓ No ↓ Yes

Develop the borehole. ←

↓

From the blow yield and the water demand in the area is it likely that the borehole will be fitted with an engine- or motor-driven pump?

↓ No ↓ Yes

Do a 5-hour constant-rate-drawdown and recovery-from-drawdown test.

Do step-drawdown and recovery-from-drawdown test, followed by a constant-rate-drawdown, lasting at least 24 hrs, and recovery-from-drawdown test.

↓ ↓

Do the tests indicate that the borehole has sufficient permeability for its intended use?

↓ No ↓ Yes

Is the borehole drilled in a fractured rock secondary aquifer? No →

↓ Yes ↓

Consider hydro-fracturing to increase the permeability and, if hydro-fracturing is carried out, retest. Keep records of both sets of tests.

↓ ↓

Are the capacity and location of the selected boreholes adequate to cater for the agreed demands? In checking this capacity ensure the figure entered for the number of hours per day each pump will operate is realistic. In the case of handpumps it is recommended to use a maximum figure of 5 hours.

↓ No ↓ Yes

Go back to the beginning of Box 6.1 and check what additional development plans must be made.

Are there any indications that the water to be pumped from the borehole will be abrasive? Developing a borehole to prevent abrasion is more effective than selecting a pump to minimise its effects.

↓ No ↓ Yes

Select the type of filter packing to be used outside the borehole casing to minimise such abrasion. ←

↓ *Continued overleaf*

Box 6.2 cont: Flowchart for borehole drilling, development and casing

↓ *Continued from previous page*

Are there any indications that the water in the borehole may be corrosive? Use local knowledge as well as the water quality tests to answer this question. Also remember that if a handpump is to be fitted to a borehole with mildly corrosive water the iron absorbed by the water from using galvanised borehole casing and/or pump components can cause it to develop a bad taste, to stain laundry and to become reddish in colour when stored and/or boiled. As a result the borehole may be abandoned by its users long before the corrosion causes structural damage to the pump (e.g. Haldorsen, 1989 p.115).

↓ No

↓ Yes

Ensure only a corrosion resistant material such as uPVC is used to case the borehole. ←

↓

Install or refurbish borehole casing and/or filter packing in accordance with the geological structure of the borehole walls, the corrosion prevention requirements and the requirements for the prevention of the transport of abrasive material prevention requirements. Leave sufficient casing material protruding above natural ground level to allow for the construction of a sturdy pump platform and any additional length required by the handpump manufacturer. Again ensure that the borehole is protected at all times from children throwing objects into it and from contamination through local polluted water seepage caused by the proximity of livestock or other risks.

↓

List any pumps to be purchased. Decide at what depth the pump cylinders are to be located, paying particular attention to the drawdown occurring in low recovery rate boreholes. The cylinder depth can usually be decided using the formula: cylinder setting depth = static water level in the dry season + drawdown depth derived from plotting the pump QH curve and the well recovery QH curve on the same graph as shown in Figures 3.7 and 3.9, with all figures being expressed in metres of water. However, to minimise sand and mud pumping, the lowest point of the pump suction should always be at least 2 m above the bottom for new drilled boreholes and 0,3 m for new large diameter hand-dug wells. These figures can be halved for old stabilised boreholes. When in doubt install the cylinder deeper without placing it closer to the bottom than specified above. Then record details of required pumping rates, pumping heads and possible variations, lengths of riser pipes, borehole inside diameters, power sources, any corrosion resistance requirements and a statement that provision is to be made for the measurement of the water level in the borehole whilst the pump is still installed.

↓

Are any of the pumps to be purchased diesel- or motor-driven pumps?

Yes →

For more specific information on pumps other than handpumps refer to literature with more detailed information on the type(s) of pumping equipment being considered (e.g. ULGS Botswana, 1990).

↓

If any of the pumps to be purchased are handpumps, continue for particular information. Otherwise continue for general information.

←

↓ No

Use this report, and in particular the contents of Box 6.3, plus all the information recorded in the development of the boreholes to help with the selection and ordering of suitable handpumps. Insist that the pump supplier also supplies installation and maintenance manuals.

Box 6.3: Guidelines for the selection of VLOM human-powered pumps

Environment	Pumping head (m) 0–12	12–40	40–60	60–80	80–100
Non-corrosive	GI	GI	GI		
Corrosive	uPVC	uPVC	SS or GRP or uPVC with additional precautions		SS or GRP
All	HDPE	HDPE (foot- and, perhaps, hand-operated)		HDPE (foot-operated)	

Possible riser pipe materials for different environments

1 The area inside the thick lines represents the range of heads within which VLOM human-powered pumps can provide an adequate reliable service for domestic and livestock water supplies at very competitive total costs provided water of suitable quality can be found in the immediate vicinity of the demand.

2 Heads up to 12 m are a special case. In this range human-powered pumps can be considered for community garden water supplies because of the lower energy requirements. Direct action plunger pumps should be considered for these duties in demographic areas where the majority of pumps fall into this range.

3 Within the area inside the thick lines the use of standard VLOM pumps is now possible and should be considered seriously since the use of appropriately designed VLOM pumps makes village-level caretaking easier and reduces total maintenance costs.

When a rigid riser pipe material is used the VLOM concept means that the pump design allows both the cylinder plunger and foot-valve to be removed without removing the pump's riser pipes. Thus the VLOM concept does not require users to depart from GI riser pipes when the water is non-corrosive. GI pipes are cheaper, and are overall easier to handle than uPVC pipes because of the current use of solvent cement as the almost exclusive means of joining the individual lengths of uPVC to minimise the frequency of fatigue failures. Proven VLOM designs with GI riser pipes for heads in excess of 40 m are, however, not readily available.

HDPE riser pipes are flexible. Pumps using such riser pipes are normally hydraulically activated and therefore do not have any connecting rods between the ground-level actuator and the pump cylinder in the water. These pumps are also commonly foot-operated. The flexible riser pipe plus the absence of connector rods means that it is relatively easy to remove the whole pump from the borehole. Thus all well designed hydraulically activated pumps with HDPE riser pipes are true VLOM pumps. In addition the best designs ensure that all the wearing parts are mounted at ground level for extra easy access.

4 In nearly all areas of South Africa the water in a significant percentage of boreholes is corrosive. In addition, most human-powered pumps are installed on boreholes with a low permeability, which results in a large drop in water level before the recovery rate equals the pumping rate. Thus when the true dynamic pumping head caused by the low permeability is taken into account, pumping heads in excess of 40 m are commonplace, and without extremely tight factory and field quality control uPVC riser pipe pumps become unreliable. Thus, in many areas of South Africa, if a single type of pump (but not necessarily a single model) is to become standard, a hydraulically activated HDPE riser pump is likely to be the best choice. A single standard pump type is beneficial from both a spares and maintenance point of view.

5 At depths in excess of 60 m the reliability of most handpumps and footpumps tends to deteriorate and the human effort required to pump any water becomes excessive. Thus for range 60 to 100 m it is wise to consider using a VLOM pump that has been specifically designed for this range of duties and for foot operation by two people.

Box 6.4: Guidelines for the installation of human-powered pumps

1 Advertise the position of pump caretaker within the community and with the assistance of the water committee select suitable persons to be trained for this position. It is usually advisable to select and to train more people than are required, to allow the final choosing of the caretaker to take place after the training course and the installation of pump(s) have been completed, to ensure that more community members understand how the pumps should be cared for and to allow for natural turnover of staff.

2 If not already done: clarify with the future customers what the pump(s) will be used for and what facilities, such as an animal drinking trough or laundry washing facilities, are needed near each pump.

Obtain drawings of suitable pump platforms incorporating all the facilities required by the future customers. The objectives of a platform are to stop contaminated water finding its way back into the borehole, to have a relatively dry area with no stagnant pools around the pump and to make it convenient for customers to manage their water containers and to operate the pump.

Bearing these objects in mind, minimum requirements will include an apron to catch spilt water, a drain to take this water away, curbing around the drain area, a raised portion on which to install the pump, other raised portions on which to place the container to be filled and full containers for lifting onto customers' heads, and finally a broader raised flat area from which to operate the pump. The drain should be an open cement channel and should end in a further channel taking any spilt water away to a garden or in an effective soakaway. Laundry facilities, including a broad area sloping towards the drain, can be incorporated into the pump platform towards the end of the cement drainage channel, provided it also has a spillage apron around it. However, extra care must be exercised with regard to animal drinking troughs, which should be at least 30 m away from the borehole. Rather than using plugs to drain water from wash basins and animal drinking troughs use suitably sized gate valves.

3 Livestock and boreholes should always be kept apart to protect aquifers from contamination. Thus a fence, covering an area of about 60 m x 60 m, should be built around any pump being installed where there are unfenced livestock, even if the primary reason for installing the pump is to provide water for the animals.

4 Obtain the necessary materials to construct the pump platform, soakaway and fencing, as applicable. Also ensure that the necessary construction tools are available as well as any pump parts which may have to be cast into the platform.

5 Build the platform incorporating the agreed facilities and cure the cement effectively for at least 7 days.

6 Disinfect the well.

7 Lay out all the materials required for installing the pump, next to the borehole. Ensure that all the necessary tools and consumables for the pump installation are available as per the supplier's instructions. Install the pump as per the supplier's instructions making sure that future caretakers and other relevant stakeholders participate fully in the work. Ensure that provision is made for monitoring the water level in the borehole whilst the pump is being installed.

8 Distribute copies of the details of the development of the well, the water quality records, the pump drawdown and recovery rate test results and the pump operation and maintenance instructions to the area water service authority, the village water service provider and the pump caretaker.

Box 6.5: Guidelines for setting up ongoing management procedures

After the pump has been installed, a number of further tasks have to continue indefinitely for the pump to operate satisfactorily. These tasks include monitoring and caring for the borehole and the pump, preventative maintenance and maintenance tasks, spares management and the collection and management of the funds necessary to carry out these tasks. In the majority of cases communities primarily demand improved water supplies to reduce the time and effort spent on collecting water. In a few cases the demand may be related to obtaining water with a better taste and/or colour. Improved health is rarely included in the reasons for demanding an improved water supply, but water supply improvement projects are an ideal time to start addressing water and hygiene-related health issues. Thus if maximisation of the benefits of a water supply project is considered, health and hygiene education and random monitoring of the quality of water stored by households become an integral part of any water project. Discuss these issues with the various stakeholders involved in the project and proceed as follows:

1 List all the tasks and how frequently they are to be carried out. Allocate responsibility for carrying out each task to a particular position within a particular institution. Ensure that a clear joint understanding, acceptance and agreement is reached with all stakeholders with respect to the allocation of these responsibilities (WHO, 1988 p. 15). Ensure that a contract is signed between the water services authority and the water service provider.

Village-level caretaking, preventative maintenance, cost recovery and system management are the most cost-effective way of organising self-contained community water supplies and the distribution portion of regional schemes. The sustainability of such an approach will depend to a large degree on the extent that the project implementation facilitated a community empowerment strategy which enabled the community to define its own goals, to assess options, and to assume responsibility for actions to achieve community agreed objectives (Hodgkin *et al.*, 1994, p. 12). However, no matter how self-reliant communities become, they will never become self-sufficient and the sustainability of water and sanitation projects will still depend on local government monitoring, auditing and supporting the village-level water service providers. Local government tasks will usually include checking that communities are maintaining an adequate operation and maintenance fund, that the village water committee is keeping in touch with customers, that the water source is not deteriorating, that the pump is being cared for, that health and hygiene issues are not being forgotten, and that spares are readily available. In the medium term in most rural areas, local government requires assistance from DWAF, DPLG, the private sector and/or overseas donors to carry out its responsibilities. The assistance should include some or all of the following: financial assistance, the temporary delegation of responsibilities, capacity building and skills training. Without decisive interventions of this nature, the rich will continue to get richer and the poor poorer (Whiteford & van Seventer, 1999).

2 Draw up job descriptions, recording books/forms and information/work-flow procedures for all the above tasks.

3 It is now time for the official pump commissioning celebration to take place. This should be organised by the village water committee and attended by all those who have a future responsibility for sustaining and maximising the benefits of the installation. Thus, as well as being a time for celebration, the occasion can be used to hand over the maintenance tools, logbooks, receipt books, etc., to reintroduce local government monitoring and support staff and the village-level caretaker and cost recovery manager (IRC, 1988 p. 62).

4 All monitoring and auditing must be evaluated to identify problems. As soon as problems or even emerging problems are identified, speedy action should be taken to resolve them with all the parties involved. In this way effective community water supply systems using both deep and shallow well human-powered pumps will be realised.

6.4 Draft plan of action for implementing recommendations

6.4.1 Specifications

An essential foundation for the implementation of the recommendations of this report is the availability of suitable purchasing and contracting specifications.

It is therefore recommended that the DWAF handpump specification be revised to reflect the findings and recommendations of this report. This specification could then be included in an enquiry issued by DWAF to establish a list of approved suppliers for a period of two years. It is also recommended that, contrary to current practice, the adjudication report recommends different pumps for different duties, and perhaps even different areas of the country, depending on a company's ability to provide back-up services. The adjudication report would then be made available to all South African handpump purchasers, not just DWAF's regional offices, to enable any purchaser to place an order without issuing a new enquiry.

An important recommendation in the report is that arrangements should be made to allow for the reading of the level of the water in the borehole whilst pumping is taking place. This facility will be used:

- to carry out occasional borehole recovery tests, which will require a series of measurements to be taken over a short period of time, and
- to take more frequent spot checks before and whilst pumping is taking place.

It has been assumed in the report that the necessary means of checking these borehole water levels should be included in the pump supplier's scope of supply. Therefore a general description of the borehole water-level measuring-facility-requirements will have to be included in the pump specification.

There is also a need for a national specification on borehole development. This specification would be divided into different sections as follows:

- consulting services,
- drilling,
- enhancement and casing,
- drawdown and recovery testing,
- water sampling and quality testing,
- refurbishment, and
- documentation.

DWAF is probably the best organisation to facilitate the writing of this specification. It is however not recommended that this specification be issued as a general national enquiry, as many borehole development service providers operate in specific areas only.

6.4.2 Demonstration projects

The production of the above specifications will pave the way for the installation of effective handpumps, but without adequate institutional arrangements and information flow the projects will not be sustainable.

As also suggested by Baumann (1996, p. 9), it is therefore recommended to set up pilot demonstration projects with the following aims:

- empowering villages to become their own water service providers,
- empowering local government to become effective project facilitators and ongoing operation, caretaking and cost recovery monitors/auditors,
- examining the role of the private sector and local government in the provision of spares and maintenance services,
- verifying and refining the recommendations set out in this report, and
- collecting and disseminating information to promote best practices.

6.4.3 National support

The support of a national coordinating organisation such as DWAF, the Mvula Trust or, perhaps, UNICEF, is required to maximise the success and impact of the demonstration projects. To do this the coordinating organisation would need to appoint a manager with the following duties:

- identification of suitable implementation partners,
- acquirement of adequate funding,
- coordination of the different demonstration projects, and
- early dissemination of demonstration project findings.

6.4.4 Filling knowledge gaps

The report also indicates a number of gaps with respect to detailed information:

- initial water drawdown and recovery curves,
- the prevalence of corrosive water and how to predict it,
- how the static water level in boreholes varies seasonally and with the longer hydrological drought cycle,
- how common it is for the maximum possible pumping rate to reduce over time as the borehole drawdown rates increase and recovery rates reduce because of clogging of the borehole pores,
- the total present-worth costs associated with the use of different types and makes of handpump at different pumping levels,
- the pumping rates achieved by users of different types and makes of handpump at different water pumping levels,
- the effectiveness of pump centralisers in increasing the reliability and pumping rates of handpumps fitted with uPVC rising mains, and
- especially if such centralisers are effective, what practical alternatives to solvent cement site joints can be purchased/developed to make the installation and removal of handpumps fitted with uPVC rising mains easier to manage.

The handpump test rig located at the Agricultural Research Council's property in Silverton, Pretoria, could be employed to check the effectiveness of centralisers in increasing the pumping rates of handpumps fitted with uPVC rising mains and to provide more information on the relative advantage of different handpump types and makes for pumping at high discharge rates.

Assuming that the test-rig tests confirmed the effectiveness of centralisers for use with uPVC riser main handpumps, this knowledge could be used to direct pump suppliers and pump manufacturing specification writers to develop alternatives to solvent cement site joints. In the meantime, would SKAT, Switzerland be willing to take up the challenge in respect of the Afridev specification (SKAT, 1994)?

But, most importantly, proper implementation of the proposed demonstration projects, together with the encouragement this will give for accurate borehole installation monitoring countrywide, could fill most of the above knowledge gaps and over time dramatically improve the effectiveness of community water supply systems using handpumps on deep and shallow wells.

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ANNEXURE A

HANDPUMP PERFORMANCE/SELECTION CRITERIA

HANDPUMP PERFORMANCE/SELECTION CRITERIA

1 **Specified pumping lift:** ______________________ m

2 **Pump manufacturer:** ______________________

3 **Pump type:** ______________________ model number

General description: ______________________

____

____

____

4 **Capacity:** ______________________ ℓ/min

for pump cylinder: operational frequency: ______________________ cycles/min

stroke length: ______________________ mm

and pump actuator: operational frequency: ______________________ cycles/min

handle stroke length: ______________________ mm

or handle diameter: ______________________ mm

Total available cylinder stroke length: ______________________ mm

5 **Pumping effort:**

Input: ______________________ watts

Maximum handle force: ______________________ Newtons

Volumetric efficiency: ______________________ %

Typical "no discharge" cycles after 12-hour idle period: ______________________ number

6 **Minimum acceptable internal well diameter:** ______________________ mm

7 **Ease of manufacture:** Describe briefly which of the components of the main pump parts require specialised production techniques and which could be manufactured in a small regional factory.

Pump cylinder: ______________________

____

____

____

Rising main: ______________________

____

____

Pumprods: ______________________

____

____

Pumpstand: ______________________

Is your organisation sympathetic to the concept of manufacturing pump components regionally and thereafter assembling main pump parts at small regional factories? Please comment: ______

8 **Ease of installation and resetting cylinder depth:** Describe what features of the pump facilitate ease of initial installation and re-installation for the purpose, for example, of setting the pump cylinder at a greater depth: ______

To what depth can the pump be installed without the use of lifting tackle? ______ m

Should the column be full of water, is there any means of releasing it to make it easier to lift the unit out of the well? ______

Mass of pump cylinder: ______ kg

Mass of 3 m length of rising main plus pumprod: ______ kg

9 **General reliability:** Describe any special features which you feel increase the reliability of the pump: ______

List all spares and the number of each a user is likely to need to keep the pump operational and in good working order for a period of 10 000 hours assuming little corrosion or abrasion: ______

10 **Corrosion resistance:** UNDP-World Bank ratings:

1 "All the downhole components of this pump are manufactured from non-corroding materials (e.g. stainless steel rods; plastic rising main; rubber, brass, stainless steel or plastic cylinder) and no combination of materials will induce galvanic action. The pumpstand has proved resistant to corrosion damage:" ______ Yes/No

2 "Most downhole components are corrosion resistant, but some small, inexpensive and easily replaced components may corrode, or only the pumpstand has suffered corrosion damage:" ______ Yes/No

3 "Downhole components and/or pumpstand are susceptible to corrosion (e.g. mild steel or **galvanised** rods, rising mains or fasteners):" ______ Yes/No

11 **Abrasion resistance:** Based on UNDP–World Bank ratings:

1 The pump has been specifically designed to minimize damage from abrasion: ______ Yes/No

2 Abrasion resistance is adequate, but some key components will need regular replacement: ______ Yes/No

3 The pump is not recommended for community use where the ingress of sand is likely: ______ Yes/No

Regardless of the rating entered for abrasion resistance above, list the order in which pump components are most likely to fail **and** the estimated pumping hours before these components will require replacing, assuming moderate ingress of sand: ______

12 **Ease of maintenance:** Describe any/all the features of the pump which reflect that it has been designed to ensure that maintenance and/or repairs can be carried out by a designated community member after a minimum of training: ______

Describe routine and/or major pump repairs which will probably require the services of a highly trained technician and/or special tools, lifting gear or workshop facilities: ______

13 **Suitability for a wide range of pumping lift duties:** What range of pumping lifts is the handpump ideally suited for:

Pumping lift 07 m: ______________ Yes/No: Capacity: ______________ ℓ/min
Pumping lift 12 m: ______________ Yes/No: Capacity: ______________ ℓ/min
Pumping lift 25 m: ______________ Yes/No: Capacity: ______________ ℓ/min
Pumping lift 45 m: ______________ Yes/No: Capacity: ______________ ℓ/min
Pumping lift 65 m: ______________ Yes/No: Capacity: ______________ ℓ/min
Pumping lift max: ______________ metres: Capacity: ______________ ℓ/min

State any special features of the pump that make it especially suited for a wide range of pumping lifts: ____

____

____

____

14 **Versatility for more general handpump duties:** Is the pump offered suitable for pumping the water delivered through a water meter and into an elevated storage tank:

__________ Yes/No. If yes, describe the sealing arrangement which caters for back pressure on the delivery side of the pump: ______________________________

____

____

15 **Versatility for multi-purpose duties:** What modifications are required **to the handpump** to convert it to the following types of drive assuming no change in pumping lift **or** capacity:

1 Petrol/diesel-, mains-electricity-, or solar-powered: ______________________

____

____

____

2 Wind-powered: ______________________________________

____

____

After the pump has been converted to 1 can it still be hand-operated? ______________ Yes/No
After the pump has been converted to 2 can it still be hand-operated? ______________ Yes/No
Assuming no change in pumping lift, what is the maximum speed at which the pump may be power-operated? ______________________________ cycles/min
Capacity at maximum speed stated above? ______________________________ ℓ/min

16 **Details of after-sales services offered:**

1 Availability of installation, maintenance and operating instructions:

a) Comprehensive and well illustrated: ______ Yes/No

b) Comprehensive but few illustrations: ______ Yes/No

c) Available but not comprehensive: ______ Yes/No

d) None available: ______ Yes/No

2 All units are to be pre-packed before delivery. Give details of main packages as follows:

No. off	Mass each kg	Length mm	Width and depth mm x mm
______	______	______	______
______	______	______	______
______	______	______	______
______	______	______	______
______	______	______	______
______	______	______	______

Sum of all packages (gross mass)? ______ kg

3 Spares:

a) Many stockists in South Africa (list attached): ______ Yes/No

b) All spares manufactured in South Africa and available ex-stock: ______ Yes/No

c) Most spares available ex-stock in South Africa: ______ Yes/No

d) Spares generally not available ex-stock in South Africa: ______ Yes/No

Address of nearest stockist of spares: ______

______

4 Other after-sales services (preferably in South Africa):

a) Give details of factory-trained and/or recommended installation and/or maintenance teams: ______

______

______

______

______

b) Give details of available in-house installation, maintenance and pump monitoring training courses: ______

______

______

______

______

c) Give details of available on-site installation, maintenance and pump monitoring training courses: ____

____

____

____

____

17 Details of major customers:

No.	Organisation	Contact person	Town and region	Tel. No.
1	______	______	______	______
2	______	______	______	______
3	______	______	______	______
4	______	______	______	______
5	______	______	______	______
6	______	______	______	______
7	______	______	______	______
8	______	______	______	______
9				

18 Product and representation planning: Detail any plans to improve existing products, your range of products or representation in South Africa: ____

____

____

____

____

____

____

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____

____

ANNEXURE B

SOUTHERN AFRICA HANDPUMP MANUFACTURERS AND IMPORT AGENTS

Annexure B: Southern Africa handpump manufacturers and import agents

Company name/Product	Postal address	Street address	Contact person	Tel/Fax
Aquatrix CC Patented Air Column Pump Afridev Handpumps? **Problem making contact**	P.O. Box 92 Wilderness 6560 South Africa	Discovery Road Pacaltsdorp Industria George	Mr Rob Dennill Mr Fanie Nel (Agent)	T (0441) 78-0555 No! T (01802) 31-526
Amanzi	P.O. Box 1255 Matsappa Kingdom of Swaziland		Mr Gilles Preat, General Manager (French)	T (09268) 8-5537/02 (09268) 505-7572 F (09268) 8-5269
BRD Engineering (was Barry Pumps)	P.O. Box 13576 Elspark Germiston 1418 South Africa	17 Makriel Street Wadeville Germiston	Ms Betty de Melo, MD Brian Barry, Marketing and Development	T (011) 824-0344 082-922-3293 F (011) 824-0447
Prodorite (Pvt) Ltd Blair Shallow Well Handpump	P.O. Box 2887 Harare Zimbabwe	21 Leyland Road Ardbennie Industrial Sites Harare	Mr BJ Tiffin, Sales Manager	T (09263) (4) 63691/5 63474 63624/5 F (09263) (4) 63696
Climax Windmills Dorbyl Light and General Engineering (Pty) Ltd Brass and SS Cylinders Lever and Wheel Pumpstands Tank Stands **Visited 23/06/'94**	P.O. Box 20244 Peacehaven 1934 South Africa	Cnr Houtkop & King Streets Duncanville Ext 3 Vereeniging	Mr H Tang, General Manager Mr Martin Dealey, Sales Manager Mr Heine Bekker, Works Manager	T (016) 23-1265 F (016) 23-3105
P G Drilling Equipment and Accessories	P.O. Box 69543 Bryanston 2102 South Africa	60 van Beek Street New Doornfontein Johannesburg	Mr Jannie Mocke	T (011) 452-1090
Bryan Kippon (Pty) Ltd Zimbabwe deep borehole Bush pump	P.O. Box 5194 Benoni South 1502 South Africa		Mr Eddie Cantrell	T (011) 493-7690 T (011) 849-7603

Cont. on next page

Annexure B cont:. Southern Africa handpump manufacturers and import agents

Company name/Product	Postal address	Street address	Contact person	Tel/Fax
Laingsdale Engineering: markets Strauss System HIBO/Hantam Pump. Manufacturer: Likflo Pumps (Pty) Ltd **Visited us 07/07/'94**	P.O. Box 226 Plumstead 7800, Cape Town Private Bag X1 Bloubergstrand 7436	3 Victoria Road Plumstead Cape Town	Mr Ellis Völlmer Mr Flip Strauss, Inventor	T (021) 797-6171 F (021) 797-6179 T/F (021) 553-1822
Aardbote bk & Play Pump SA formerly Merssa cc	P.O. Box 523 Sundra 2200 South Africa	Small Holding 236 Modderfontein	Mr Ronnie Stuiver, Manager Mr Hennie Schoeman, Marketing	T (0157) 661-1444 (011) 965-1270 082-651-1740 F (0157) 661-1444
Metal and Engineering Industries (Pty) Ltd Trading as National Pump Cast lever pumpstand Cast wheel pumpstand Powerheads **Visited 08/06/'94**	P.O. Box 38070 Booysens 2016 South Africa	8 Garland Street Ophirton Johannesburg	Mr Wynand Labuschagne, Works Manager	T (011) 493-6520 T (011) 493-0853
New Dawn Engineering Afridev Handpumps	P.O. Box 3223 Manzini Swaziland		Crispin R Pemberton-Pigott	T (09268) 8-5016 8-4194 F (09268) 8-5016 H (09268) 5-5497
Nimric Investments (Pty) Ltd Lever pump stands Wheel power head with handle (Windmills & Tank stands) **Visited 13/06/'94**	P.O. Box 359 Hammanskraal 0400 South Africa	43 Seventh Street Between 6 & 8th Streets Babelegi	Mr Chris Lister, General Manager Mr Johan Bekker, Sales Manager	T (01464) 78-319/463/585 F (01464) 78-318
Pulsa Agent in RSA			Geraldine Downey	Pager (031) 207-2000 code 9090
SA Valve & Engineering (Pty) Ltd Brass cylinders etc Lever pump stands **Visited 13/06/'94**	P.O. Box 133 Hammanskraal 0400 South Africa	Factory Flat A1 11th Street Babelegi	Mr Robert Hitchens Owner/GM Mr Colin Anderson Works Manager	T (01464) 79-069 F (01464) 79-086

Cont. on next page

Table 4.1 cont: Southern Africa handpump manufacturers and import agents

Company Name/Product	Postal Address	Street Address	Contact Person	Tel/Fax
Rural Industries Promotions The Thebe Pump	Private Bag 11 Kanye Botswana			T (09267) 34-0392/3
Turbo Pumps (Pty) Ltd **Visited 04/07/'94**	P.O. Box 838 Silverton 0127 South Africa	284 Price Street Waltloo Pretoria	Mr R T Cohen	T (012) 83-2321/2/3 F (012) 803-6246
Van Rensburg Afridev handpump **Problem making contact**	P.O. Box 999 Rustenburg 0300 South Africa		Mr AWJ van Rensburg	T (0142) 20737?
Van Staden Pumps Conbrako (Pty) Ltd	P.O. Box 4018 Luipardsvlei 1743 South Africa	44 Jacob Street Chamdor	Mr Brian Child	T (011) 762-2421 F (011) 762-6535
Vergnet Pumping Systems cc	P.O. Box 53508 Kenilworth 7745 South Africa	Cape Town	Mr John Carter South African Representative for Vergnet SA France	T (021) 794-4125 F (021) 794-0898 (021) 797-4114
WESA **Visited 28/06/'94**	P.O. Box 9400 Johannesburg 2000 South Africa	63 Plantation Rd Eastleigh Edenvale	Mr Manfred Gollnhuber	T (011) 609-1033 F (011) 452-6231
Mono Pumps (Africa) (Pty) Ltd **Visited 28/06/'94**	P.O. Box 8136 Edenglen 1613 South Africa	13 Engwena Road Sebenza Edenvale 1610	Mr Steven Rose, Sales Manager Peter du Preez, Product Manager	T (011) 609-4150 F (011) 452-6266
Orbit Pump Manufacturing (Pty) Ltd **Visited 05/07/'94**	P.O. Box 18127 Rand Airport 1419 South Africa	Graphite Street Driehoek Germiston	Mr Herbert Peake, Managing Director Mr Rudling, Sales Manager Mr Patrick Taylor, Sales	T (011) 873-4007/8/9 F (011) 873-3182
Cemo Pumps (Pty) Ltd	P.O. Box 27023 Benrose 2011 South Africa	64 Hanau St Benrose Johannesburg	Mr H Crown	T (011) 618-2003 082-601-1621 F (011) 618-3139

ANNEXURE C

HANDPUMP PURCHASERS' QUESTIONNAIRE

DEVELOPMENT OF
EFFECTIVE COMMUNITY WATER SUPPLY SYSTEMS
USING DEEP AND SHALLOW WELL HANDPUMPS

A WATER RESEARCH COMMISSION FUNDED PROJECT
BEING IMPLEMENTED BY
THE DEVELOPMENT SERVICES AND TECHNOLOGY PROGRAMME
ENVIRONMENTEK, CSIR

HANDPUMP PURCHASERS' QUESTIONNAIRE

PRETORIA
April 1996

Dear Respondent,

We would like to thank you for the time that you spend on this questionnaire. The information gathered will be of great benefit to us.

OBJECTIVES OF THE HANDPUMP PURCHASERS' QUESTIONNAIRE

The main objectives of this questionnaire are to:

- survey current practices with respect to handpump selection, project implementation and ongoing pump care,
- ascertain how purchasers perceive handpumps should be selected,
- ascertain how purchasers suppose effective handpump projects are implemented,
- evaluate the gaps between current practice, what people generally regard as best practice and highlight problem areas, and
- look at the scope for both deep and shallow well handpump use in South Africa.

Project implementation encompasses all aspects of the initial installation which are likely to influence the long-term success of the project. These aspects include the selection and development of the borehole, community participation and control during all phases of the project, capacity building and pump care training as well as handpump selection and installation.

The information gained from these questionnaires together with information gained from:

- a literature survey
- visiting pump manufacturers
- comparing and contrasting South Africa with other developing countries, and
- implementing a "pump users' questionnaire"

will be used to assess the potential for the use of handpumps specifically developed for village level operation and maintenance/management (i.e. VLOM handpumps). The information will also be used to assess the potential for community-based pump care, community-based management of maintenance, and decentralised maintenance.

At the end of the above surveys, assuming reasonable response, it is hoped to implement a pilot study to test these concepts further. The questionnaire ends with the question whether your organisation is interested in forming a partnership with the CSIR to implement the pilot study. Please consider this question carefully before returning your reply.

NOTE: It is not essential that respondents fill in their name and address and this information will not appear on any report produced. It is however being requested for the research team's contact and follow-up purposes.

A self-addressed envelope has been included. It will be appreciated if you would return the completed questionnaire within **two weeks** of receiving it. This will enable us to process your information and to complete this section of the project without delay.

If you would like further clarity on any of the questions or on the study itself, please feel free to contact us at the following:

CSIR Environmentek
Water Resources Management Programme
PO Box 395
PRETORIA
0001 South Africa

Tel: +27 12 841-2341
Fax: +27 12 841-3954

or at

TSE Water Services
57 Twelfth Street
ORANGE GROVE
2192 South Africa

Tel/fax: +27 11 640-6543

Thank you for your time. Your cooperation is greatly appreciated,

Derek Hazelton
Project Leader

Monique Meiring
Lead Sociologist

DEVELOPMENT OF EFFECTIVE COMMUNITY WATER SUPPLY SYSTEMS USING DEEP AND SHALLOW WELL HANDPUMPS

A WATER RESEARCH COMMISSION FUNDED PROJECT BEING IMPLEMENTED BY THE DEVELOPMENT SERVICES AND TECHNOLOGY PROGRAMME, ENVIRONMENTEK, CSIR

HANDPUMP PURCHASERS' QUESTIONNAIRE

Section 1: Details of respondent

1.1 Today's date: (yy/mm/dd)

/	/	/

1.2 Type of company:

Government		NGO		Consultant		Other	
If other, please specify							

1.3 Name: (Optional question)

1.4 Name of the company that you represent: (Optional question)

1.5 What position do you hold in this company? (Optional question)

1.6 Address where you can be contacted: (Optional question)

	code	

1.7 Telephone number where you can be contacted: (Optional question)

code		

1.8 Telefax number where you can be contacted: (Optional question)

code		

Section 2: Details of the purchases

2.1 How many handpumps have you or your organisation purchased in the last 12 months?

2.2 Analysis of pumps purchased: (If this information is not freely available, please attempt to answer as much as possible.)

Company's name where purchased	Type	Make	Model	Cylinder diameter (mm)	Range of installation depths (m)	Number purchased

2.3 What is the approximate value of the pumps purchased?

R

2.4 Name the geographical area for which the pumps were purchased.

Section 3: Details of current purchasing practice

3.1 Do you have a standard tender document that you issue with handpump enquiry documents?

Yes		No	
If "yes" please attach a copy.			

3.2 Do you use a standard method for adjudicating tenders?

Yes		No	

If "yes", please attach a copy. (Preferably a completed adjudication report rather than a blank document)

3.3 What criteria are taken into account by your organisation when purchasing handpumps?

3.4 Are there any additional criteria?

3.5 Have you had any feedback from users as to how the pumps have performed?

Yes		No	

If "yes"and it concerns the problems that they have, please describe briefly the main problems that users have with handpumps which limit their effectiveness and/or cause them to fail. If possible, describe these problems in order of importance.

3.6 Is the handpump users' committee involved during the purchasing process?

Yes		No	

If "yes", how?	

Section 4: Details of current operation and maintenance support

4.1 How are pumps handed over to the user?

4.2 What type of training, if any, is given to the community concerning the care and maintenance of the pump?

4.3 Who is responsible for this training?

4.4 Who is responsible for maintaining the pumps that have been installed?

4.5 If your company is responsible:

Please describe briefly, how maintenance is organised.	

4.6 Does maintenance occur from one central point or is it decentralised?

From one central point?		Decentralised?	
If "yes", how many points are there?			

4.7 Is any of the work sub-contracted to private organisations?

Yes		No	

If "yes", please state the approximate value of the work				R
Also please give details of the person/organisation carrying out the work				
Name				
Address				
			Code	
Tel no (incl code)		Fax no (incl code)		

4.8 How do communities report pump failures and how is remedial action taken?

4.9 In many areas of South Africa roughly 50% of installed handpumps are inoperable at any one time. In your area what is this percentage?

%

Section 5: Details of respondent's requirements for the development of effective water supply systems using handpumps

Introduction: Please read each statement carefully. Decide the extent to which you agree or disagree with the statement that you are reading. Then place an "X" in the box on the right which most accurately describes your judgement of the statement. At the end of the section there is space in which you can enter any additional comments that you would like to make.

	Strongly agree	Somewhat agree	Somewhat disagree	Strongly disagree	Not sure
1 For installations to be effective, the community must be behind the choice of handpumps for their water supply.	☐	☐	☐	☐	☐
2 Communities generally do not favour handpumps.	☐	☐	☐	☐	☐
3 For handpump installations to be effective, the community must have chosen handpumps from a well informed position.	☐	☐	☐	☐	☐
4 For handpumps to be effective, it is essential that the installation, from the drilling of the borehole to the setting of the handpump's cylinder at the correct depth, is professionally carried out.	☐	☐	☐	☐	☐
5 Rural communities should receive adequate water supplies free-of-charge and should only pay for water when individual households have yard connections.	☐	☐	☐	☐	☐
6 Equitable cost recovery is an essential component of successful handpump installations.	☐	☐	☐	☐	☐
7 Full-cost recovery, including capital repayments, is an essential component of sustainable handpump installations.	☐	☐	☐	☐	☐
8 Sufficient institutional capacity within a community to care for the pump(s) on a day-to-day basis is essential for sustainable handpump installations.	☐	☐	☐	☐	☐
9 Sufficient institutional capacity within a community to manage cost recovery is essential for successful handpump installations.	☐	☐	☐	☐	☐
10 Before installing a handpump on a borehole, the yield of the borehole should be tested.	☐	☐	☐	☐	☐
11 Before installing a handpump on a borehole, the quality of the water should be analysed.	☐	☐	☐	☐	☐
12 It is unreasonable to expect individual communities to be completely self-sufficient. It is therefore essential that any district in which handpumps are to be installed has an adequate repair network in operation.	☐	☐	☐	☐	☐

	Strongly agree	Somewhat agree	Somewhat disagree	Strongly disagree	Not sure
13 It is unreasonable to expect individual communities to be completely self-sufficient. It is therefore essential that any district in which handpumps are to be installed has an adequate spares network in operation.	☐	☐	☐	☐	☐
14 Community water supply schemes are a waste of good money. Only large centralised bulk schemes result in reliable rural water supplies.	☐	☐	☐	☐	☐
15 Handpump installations should be carried out in a manner that allows the level of the water to be checked whilst the pump is still in the hole.	☐	☐	☐	☐	☐
16 Being lighter and easier to handle, plastic riser pipes are ideal for community handpumps and should be used more widely.	☐	☐	☐	☐	☐
17 Because of problems with joining and general reliability, plastic riser pipes should only be considered when corrosion is a problem.	☐	☐	☐	☐	☐
18 Communities generally do not favour handpumps because they have to walk long distances to collect water.	☐	☐	☐	☐	☐
19 Communities generally do not favour handpumps because they experience handpumps as being unreliable.	☐	☐	☐	☐	☐
20 Handpumps are only useful as a back-up supply when other supplies fail.	☐	☐	☐	☐	☐
21 We must standardise on one or two pumps in a given area.	☐	☐	☐	☐	☐
22 Pumps must be purchased to a strict specification.	☐	☐	☐	☐	☐
23 Pumps must be designed to facilitate community level maintenance.	☐	☐	☐	☐	☐
24 Purchasers should use price as the sole criteria to decide which pump to purchase.	☐	☐	☐	☐	☐
25 The back-up service provided by the pump seller is an essential criteria to be considered when purchasing a handpump.	☐	☐	☐	☐	☐
26 Pump corrosion can be ignored when purchasing a handpump.	☐	☐	☐	☐	☐
27 Pump abrasion can be ignored when purchasing a handpump.	☐	☐	☐	☐	☐
28 Progressive cavity pumps are superior to piston pumps for all handpump duties except maybe low heads up to 10 m.	☐	☐	☐	☐	☐
29 People generally want pumps that deliver the most water even if this makes them a bit more difficult to operate.	☐	☐	☐	☐	☐

	Strongly agree	Somewhat agree	Somewhat disagree	Strongly disagree	Not sure
30 Ease of operation is more important than the rate at which water is delivered.	☐	☐	☐	☐	☐
31 People prefer wheel-operated pumps to lever-operated pumps.	☐	☐	☐	☐	☐
32 People prefer lever-operated pumps to wheel-operated pumps.	☐	☐	☐	☐	☐

Are there any additional comments that you would like to make?

Section 6: Final

6.1 The CSIR has almost completed a survey of handpumps available in South Africa. We are currently carrying out a limited survey of handpump purchasers and handpump users. After these surveys are complete we hope to carry out a pilot study to test some VLOM handpumps in the field and to test the concepts of:

- community-based pump care,
- community-based management of maintenance, and
- decentralised maintenance through a set of training programmes.

Would your organisation, or more specifically your branch of your organisation, be interested in forming a partnership with the CSIR to implement such a pilot study?

Yes		No	

Comments and/or queries:	

6.2 The findings of this research should be available by early 2001. If you are interested in receiving a brief description of the findings of this research, to which you have contributed, please indicate to which address this information should be sent.

Yes		No			
Address					
				Code	

6.3 Please check, if relevant to you, that you have included:

a copy of a tender document		a copy of a adjudication report	

CSIR Environmentek
Development Services and Technology
PO Box 395
PRETORIA
0001 Gauteng

Tel: (012) 841-2341
Fax: (012) 841-3954

Thank you very much for your time and co-operation.

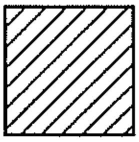
ANNEXURE D

HANDPUMP PURCHASERS' QUESTIONNAIRE:

BARCHART REPRESENTATION OF RESPONSES TO STATEMENTS

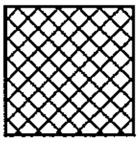
Handpump purchasers' survey: key to barchart fill codes

1 Purchasers in South Africa

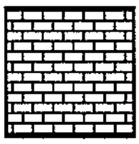


Northern Province (3 replies)

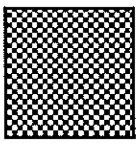
Gauteng (2 replies)



North West Province (1 reply)

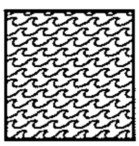


KwaZulu-Natal (4 replies)

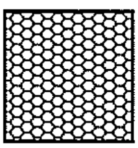


Eastern Cape (5 replies)

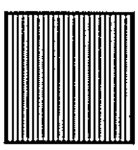
2 Purchasers from the rest of the world



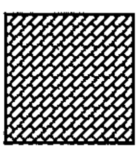
Asia (1 reply Pakistan and 1 Sri-Lanka)



West Africa (2 replies Ghana)



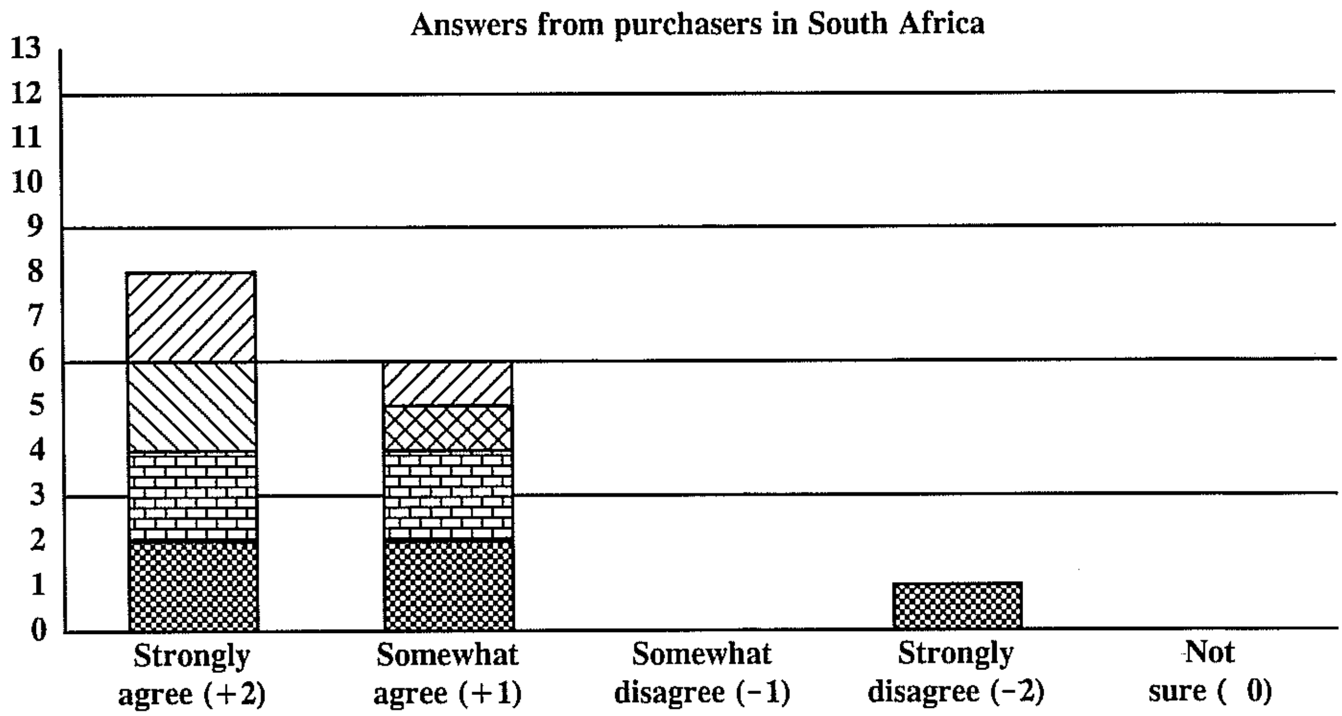
East Africa (1 reply Uganda)

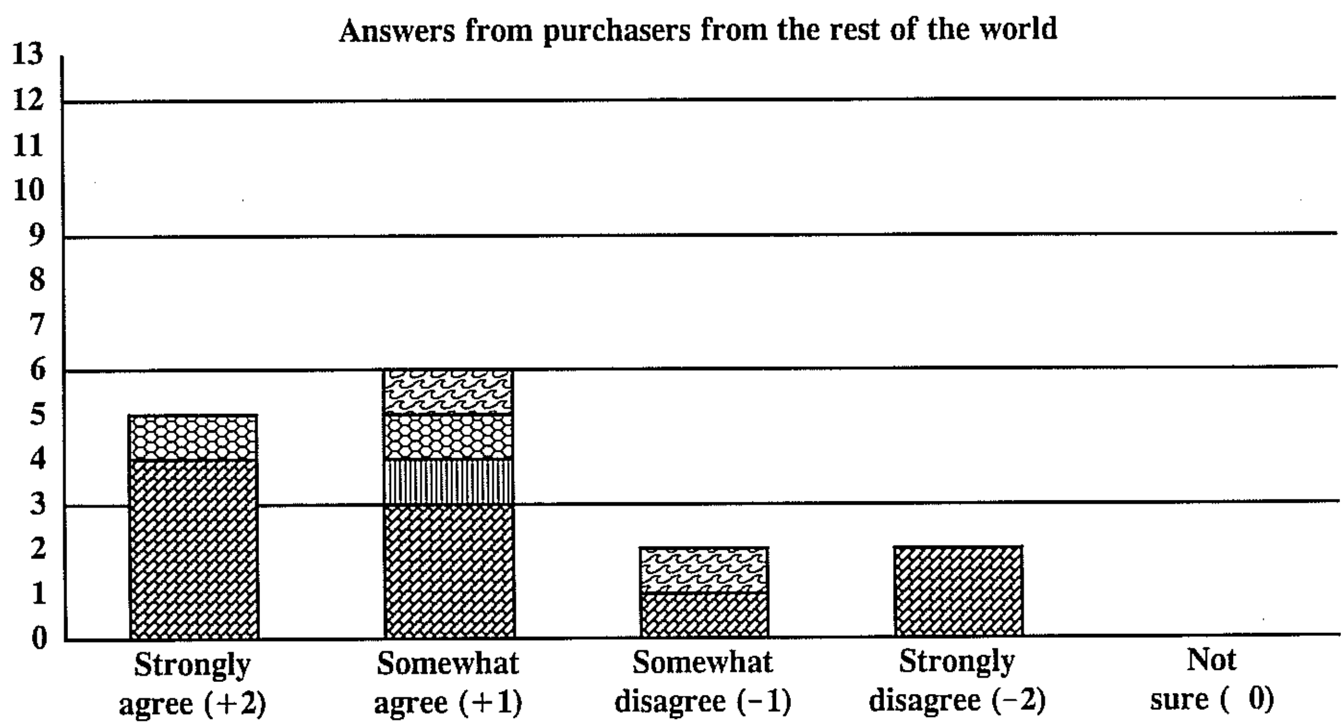


Rest of SADC (1 reply Botswana, 1 Lesotho, 2 Malawi, 2 Mozambique
1 Namibia, 2 Swaziland and 1 Zimbabwe)

Handpump purchasers' survey: statement 1

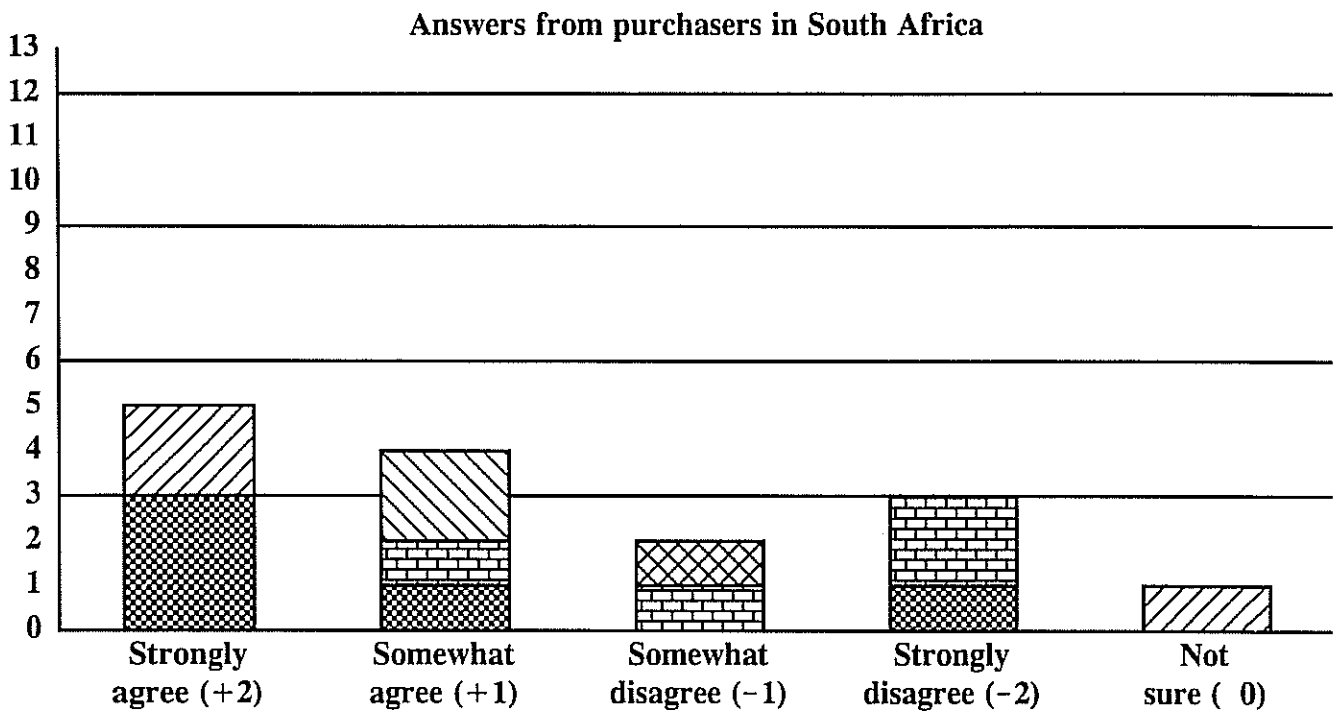
For installations to be effective, the community must be behind the choice of handpumps for their water supply.

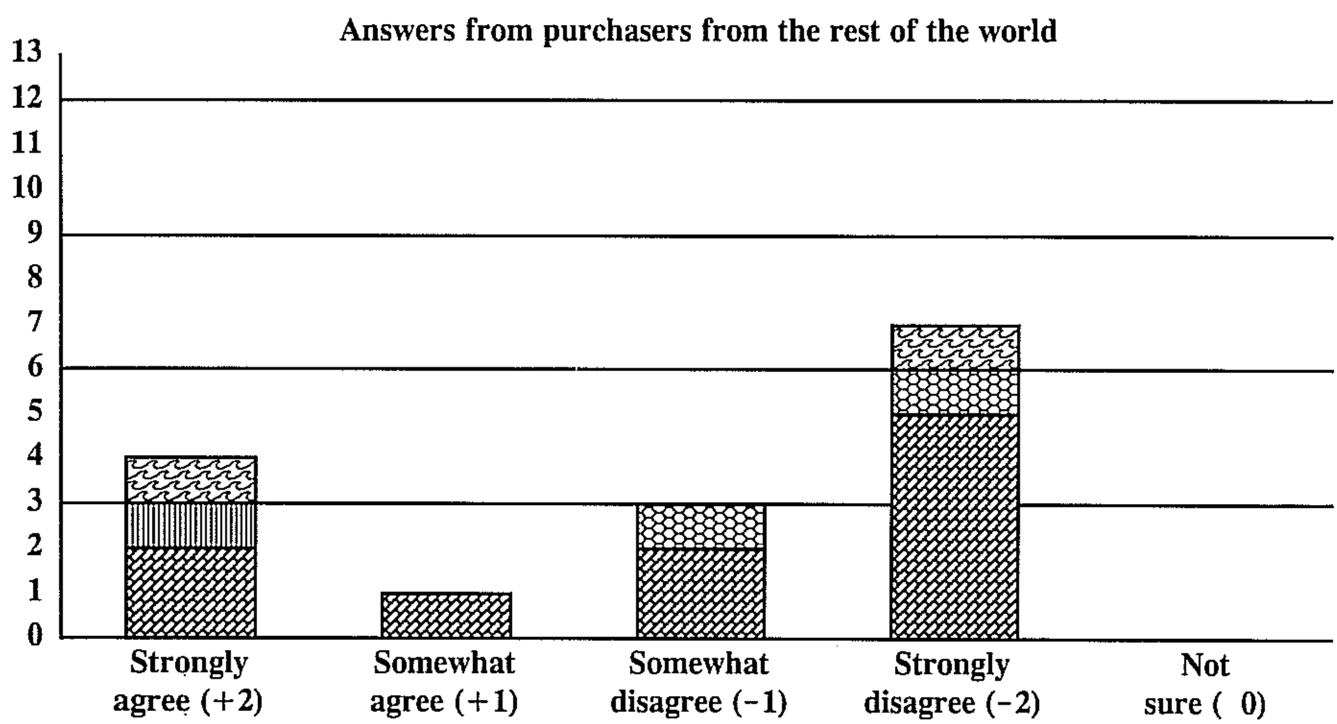




Handpump purchasers' survey: statement 2

Communities generally do not favour handpumps.

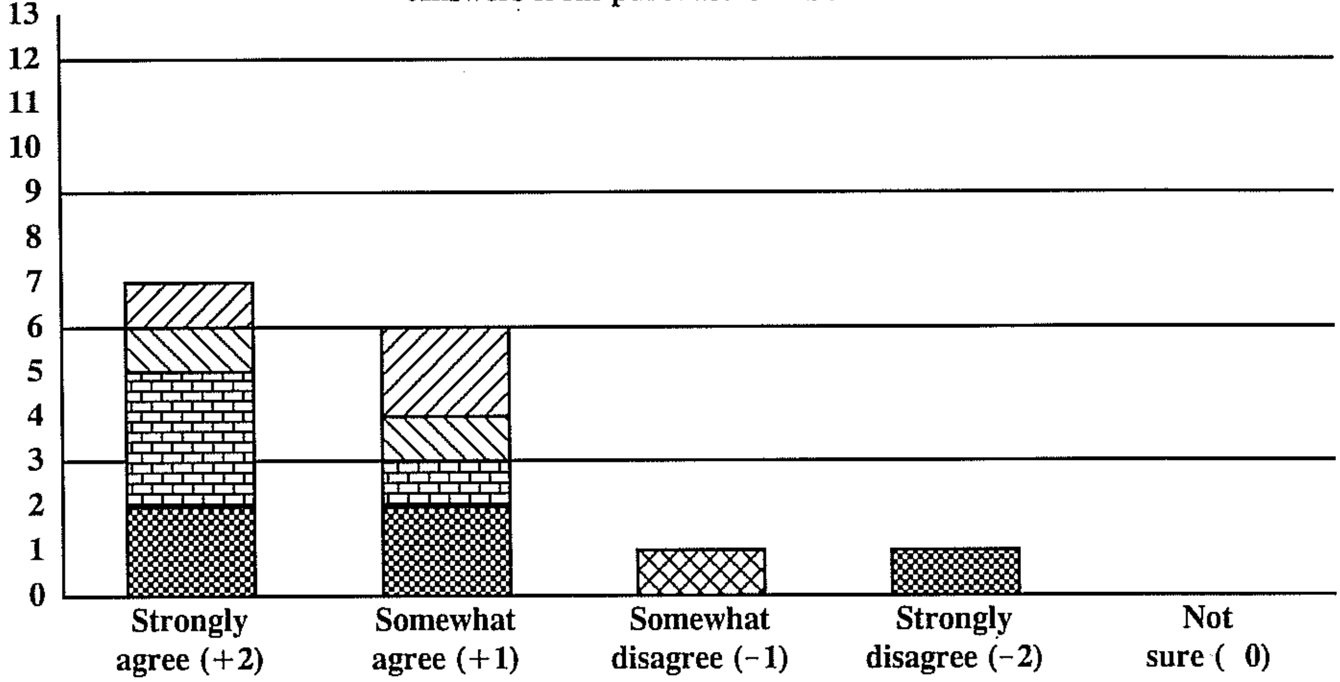




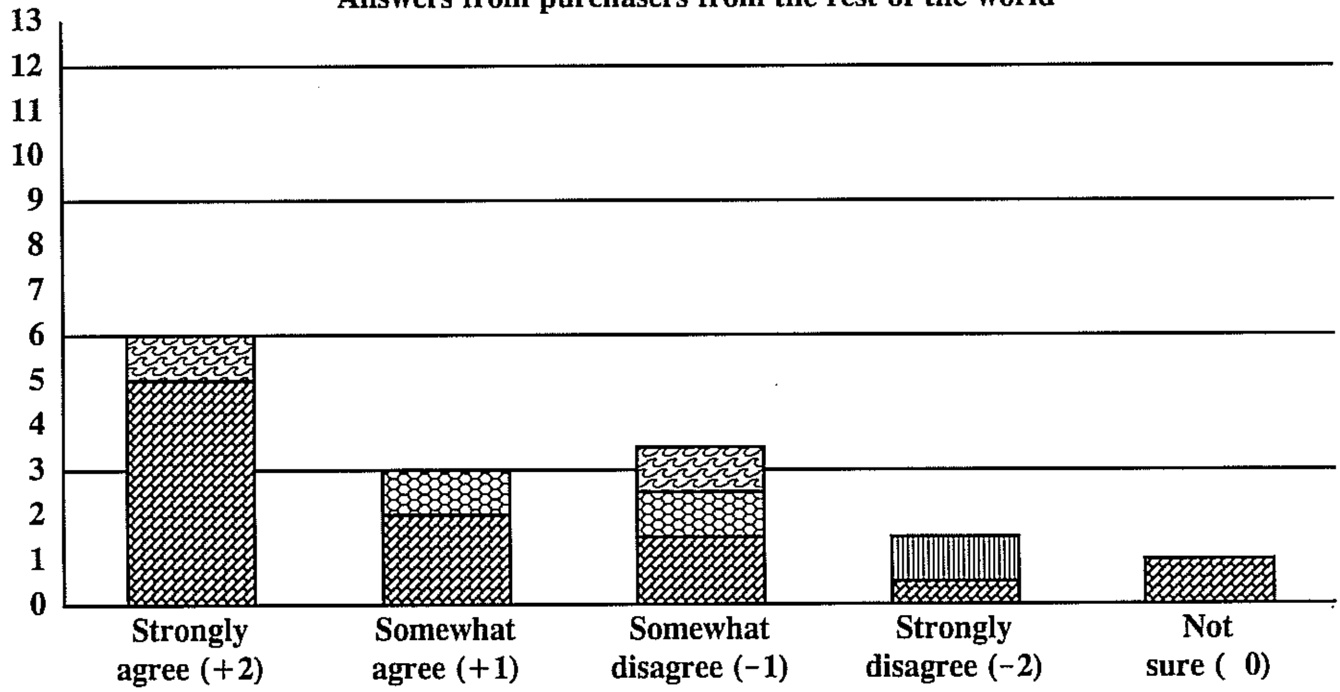
Handpump purchasers' survey: statement 3

For handpump installations to be effective, the community must have chosen handpumps from a well informed position.

Answers from purchasers in South Africa

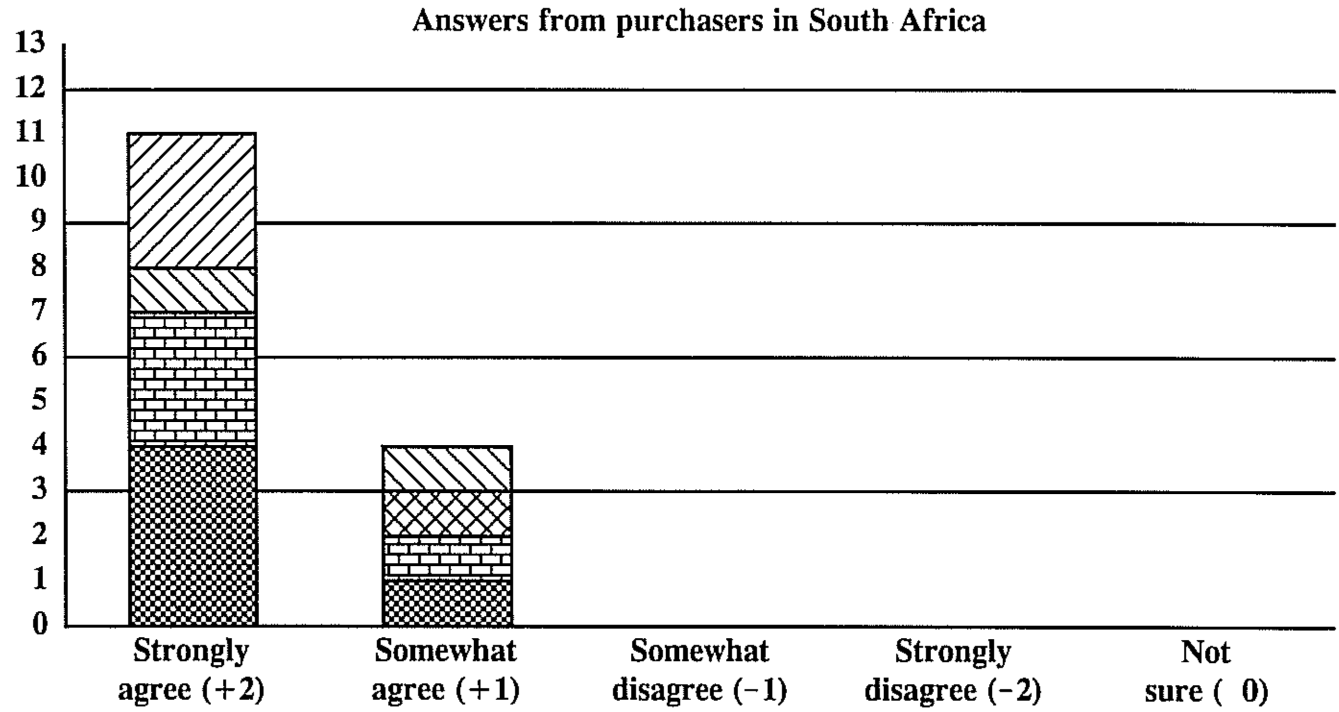


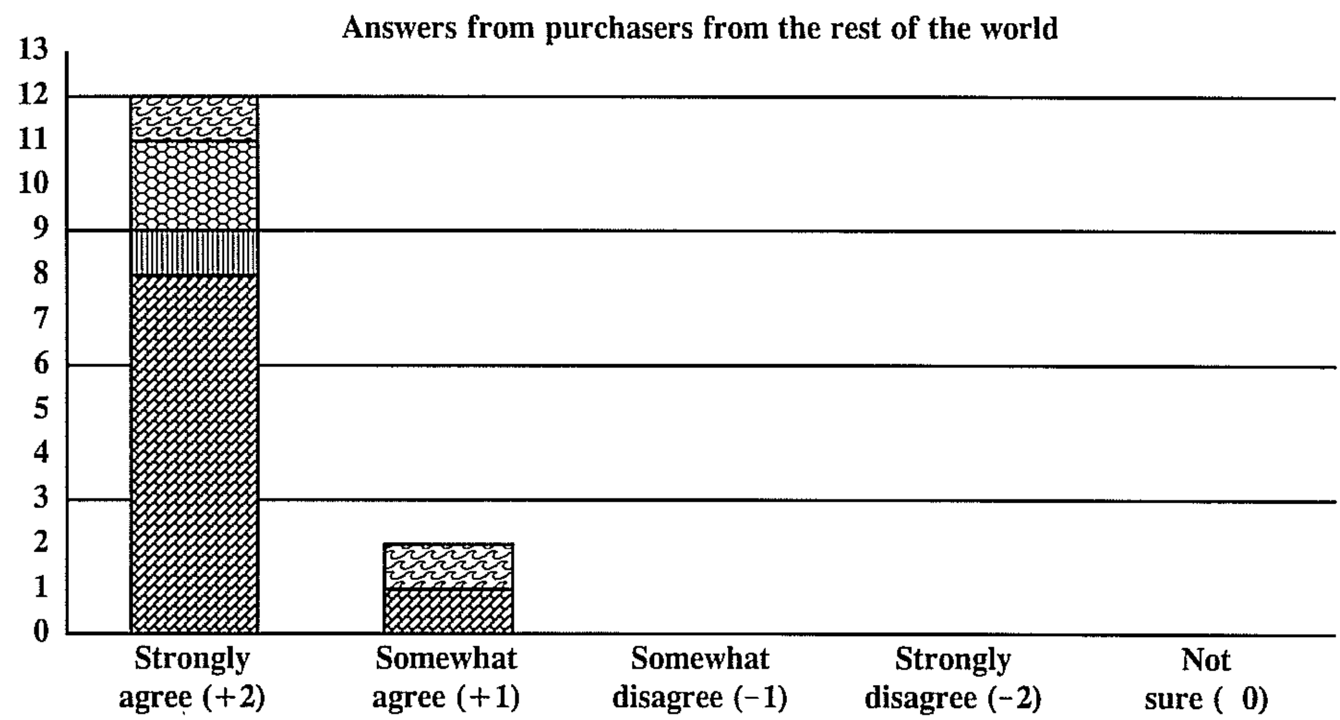
Answers from purchasers from the rest of the world



Handpump purchasers' survey: statement 4

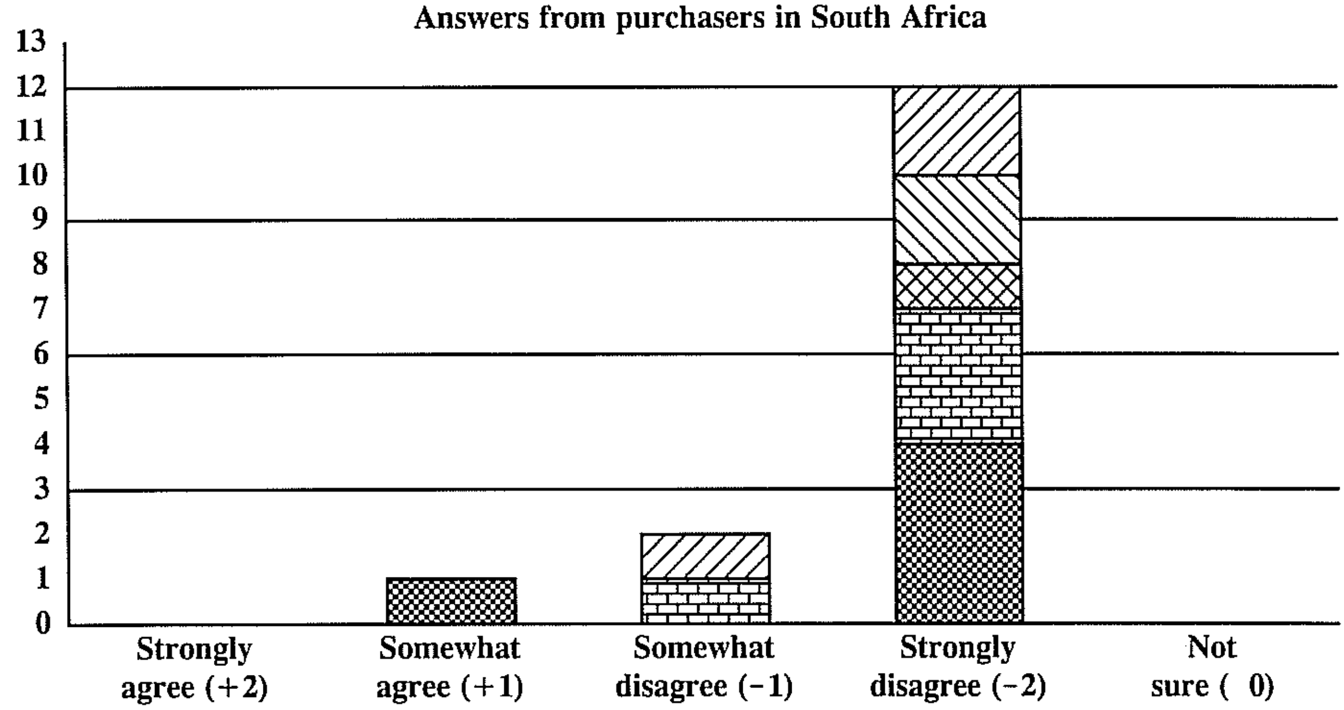
For handpumps to be effective, it is essential that the installation, from the drilling of the borehole to the setting of the handpump's cylinder at the correct depth, is professionally carried out.

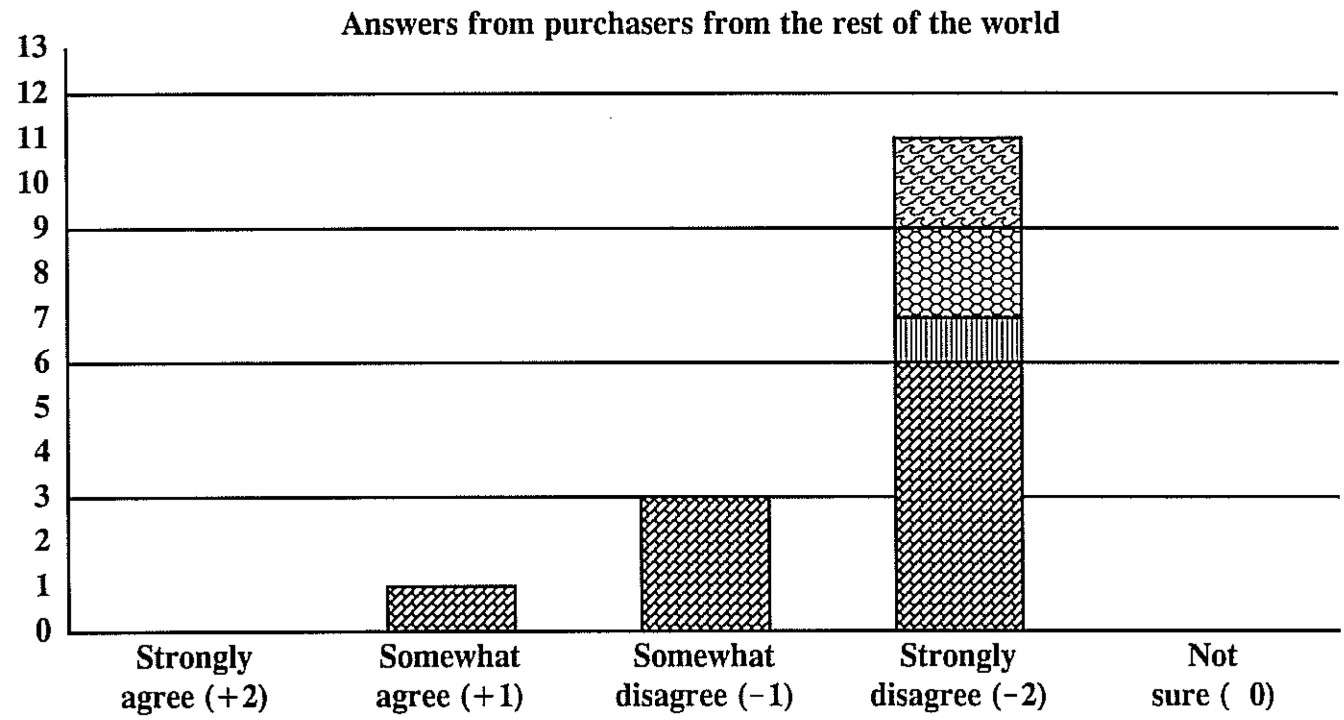




Handpump purchasers' survey: statement 5

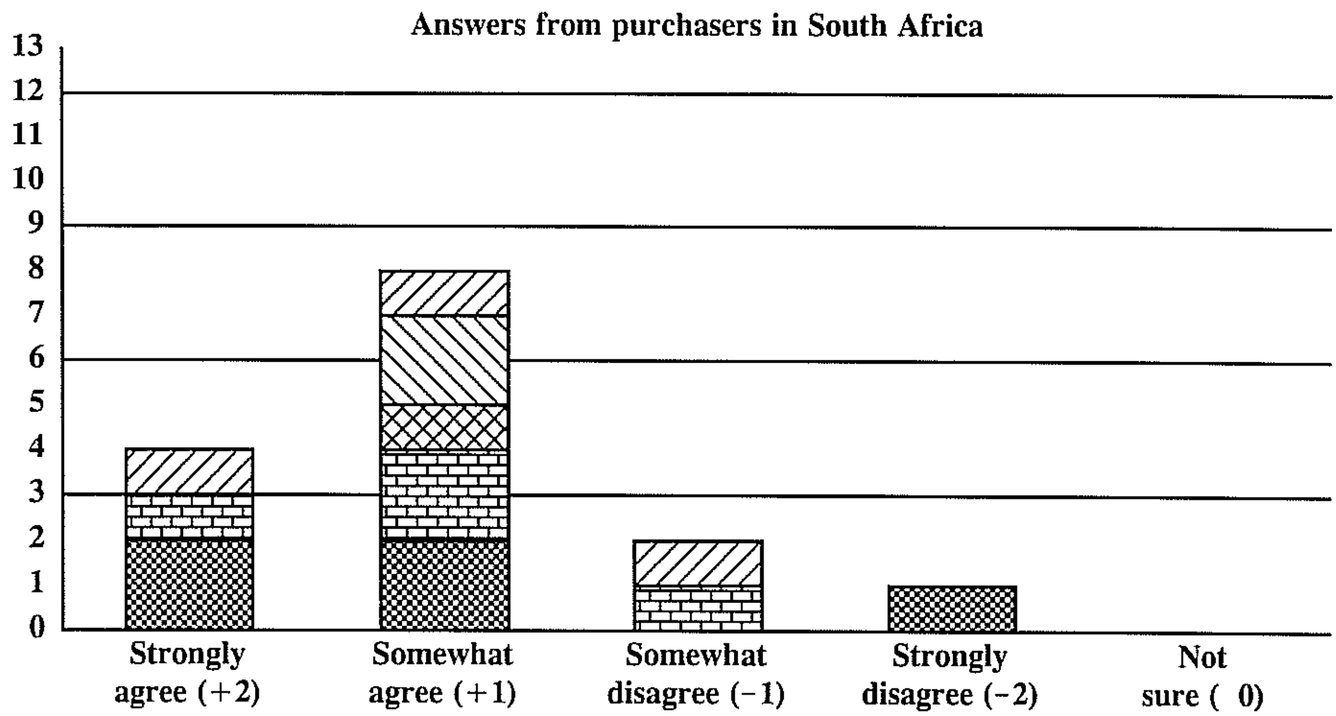
Rural communities should receive adequate water supplies free and should only pay for water when individual households have yard connections.

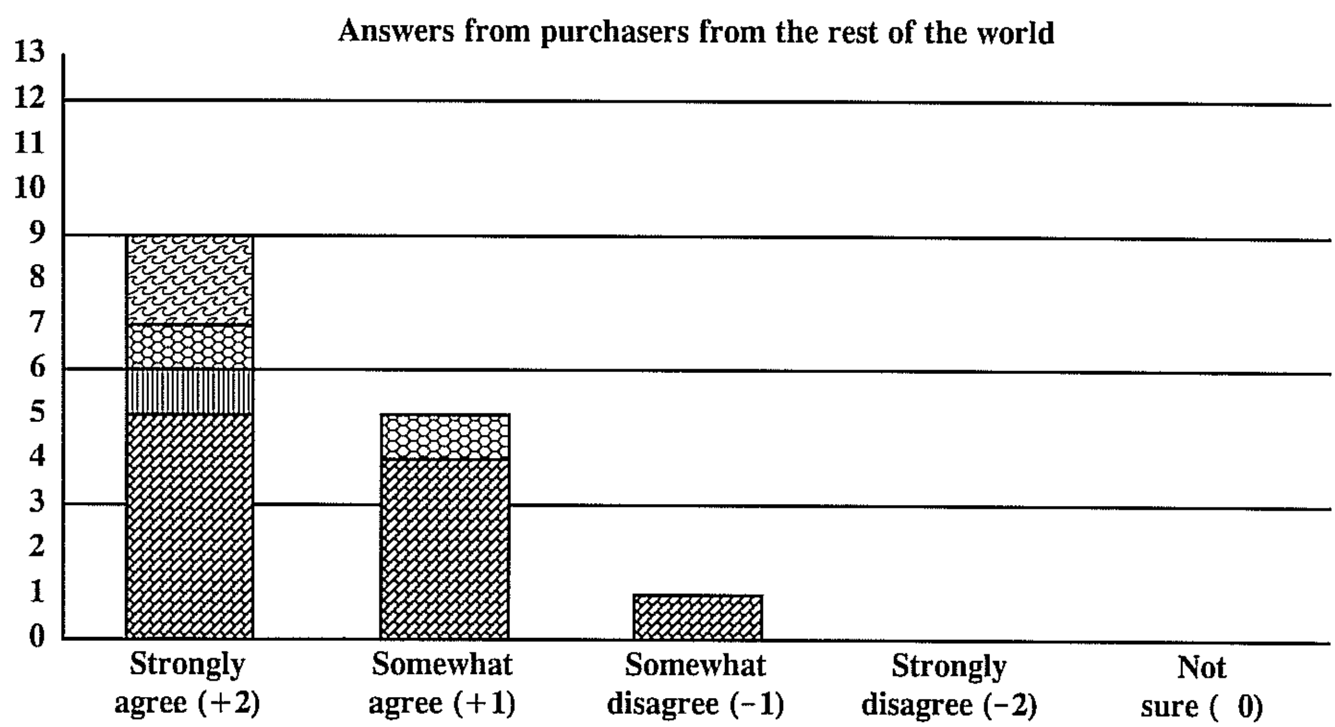




Handpump purchasers' survey: statement 6

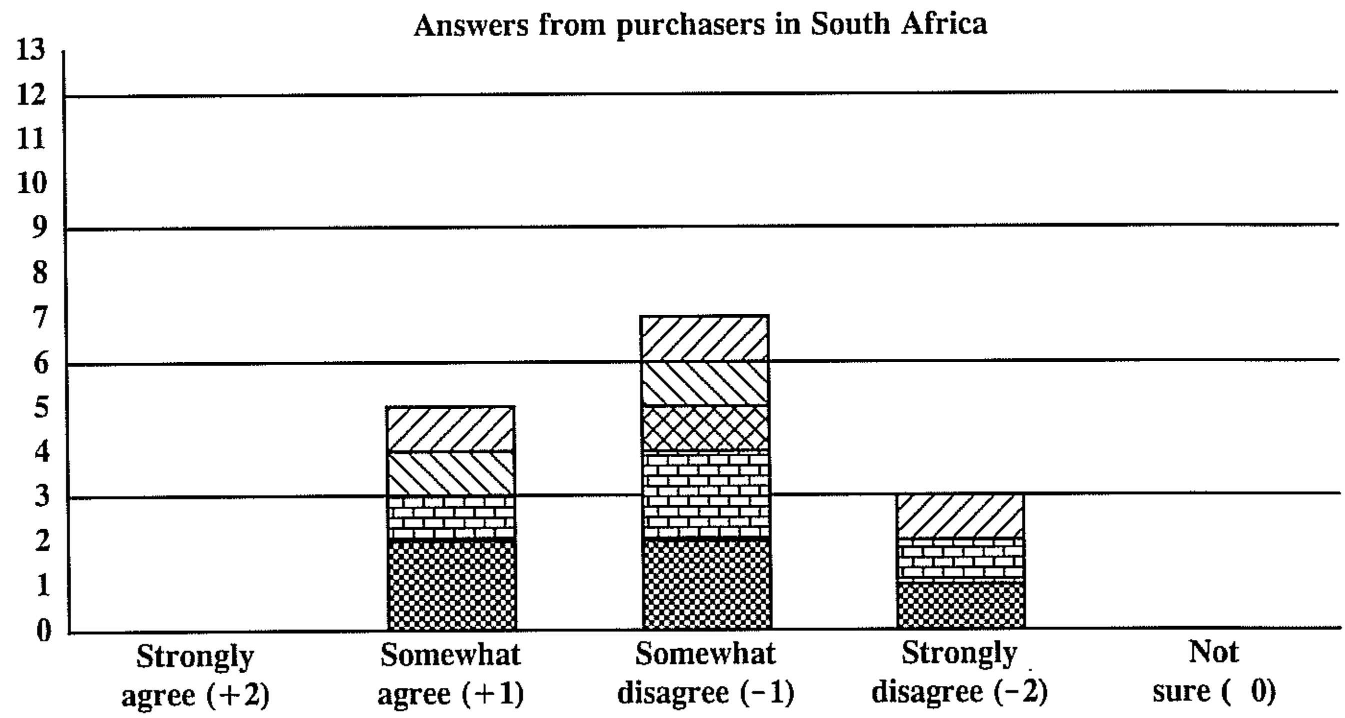
Equitable cost recovery is an essential component of successful handpump installations.

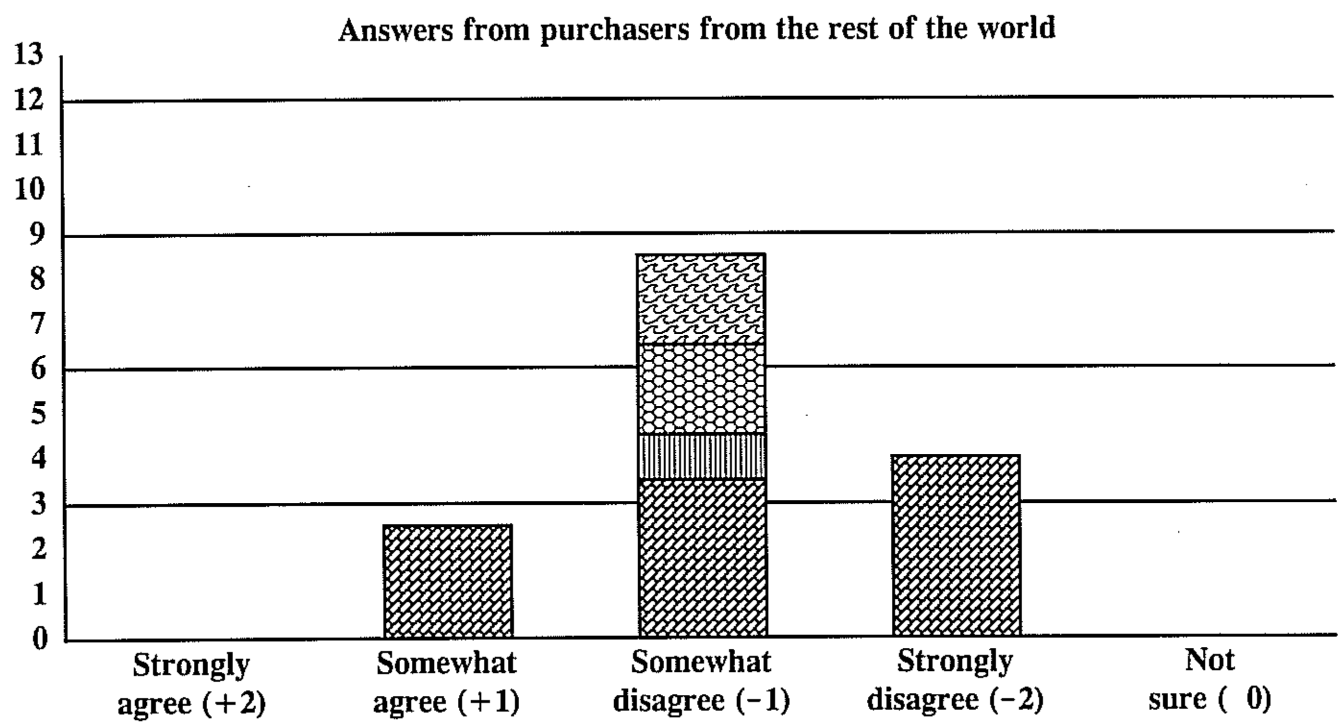




Handpump purchasers' survey: statement 7

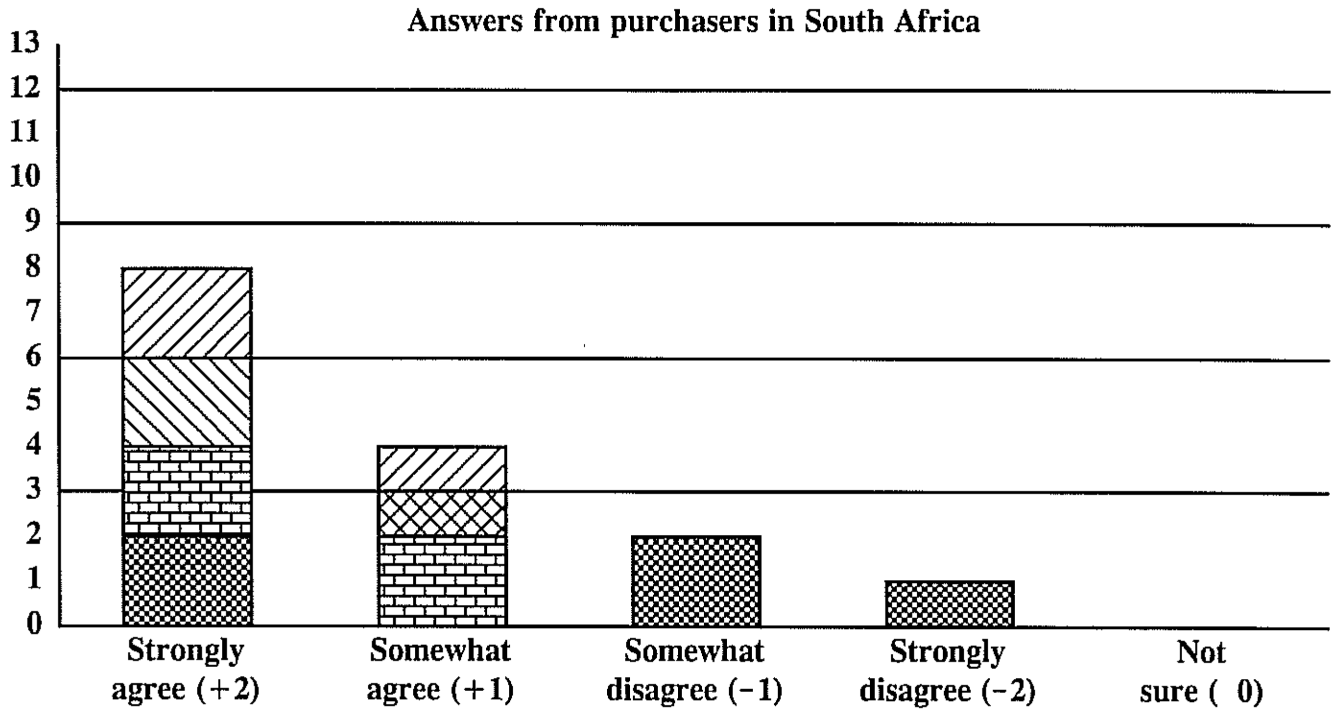
Full cost recovery, including capital repayments, is an essential component of sustainable handpump installations.

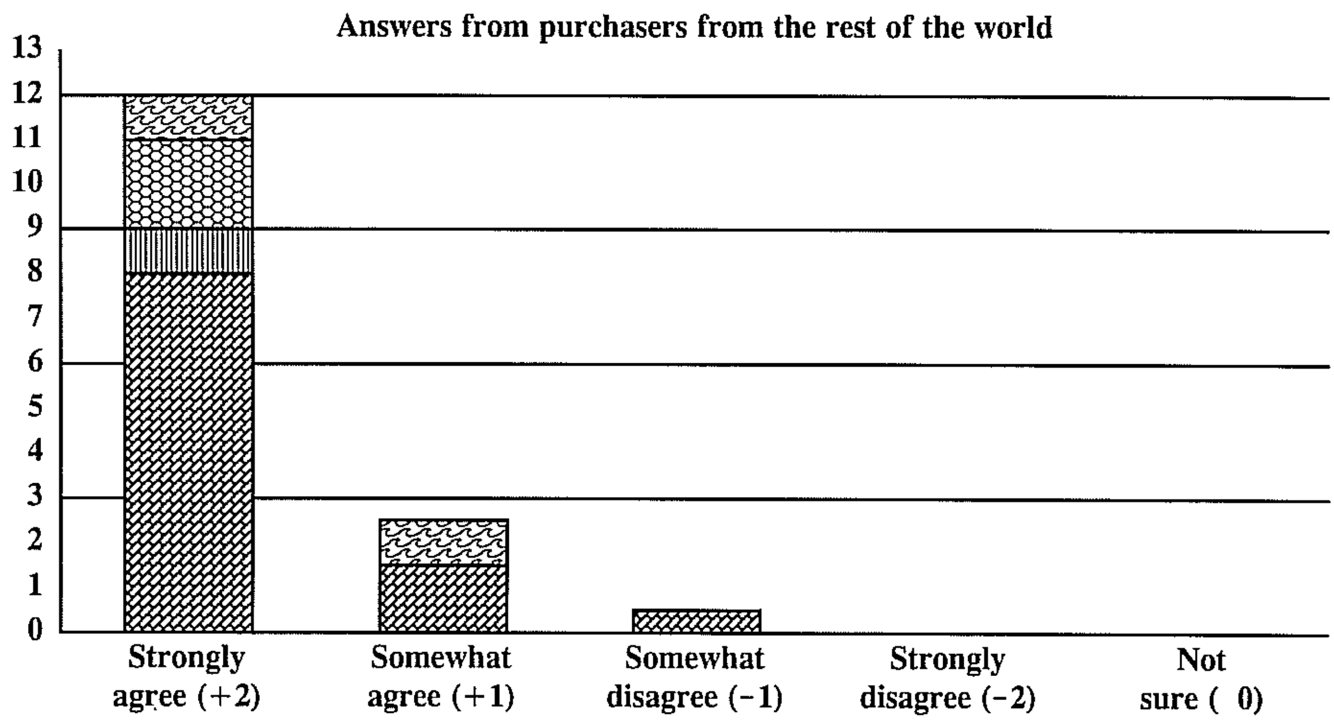




Handpump purchasers' survey: statement 8

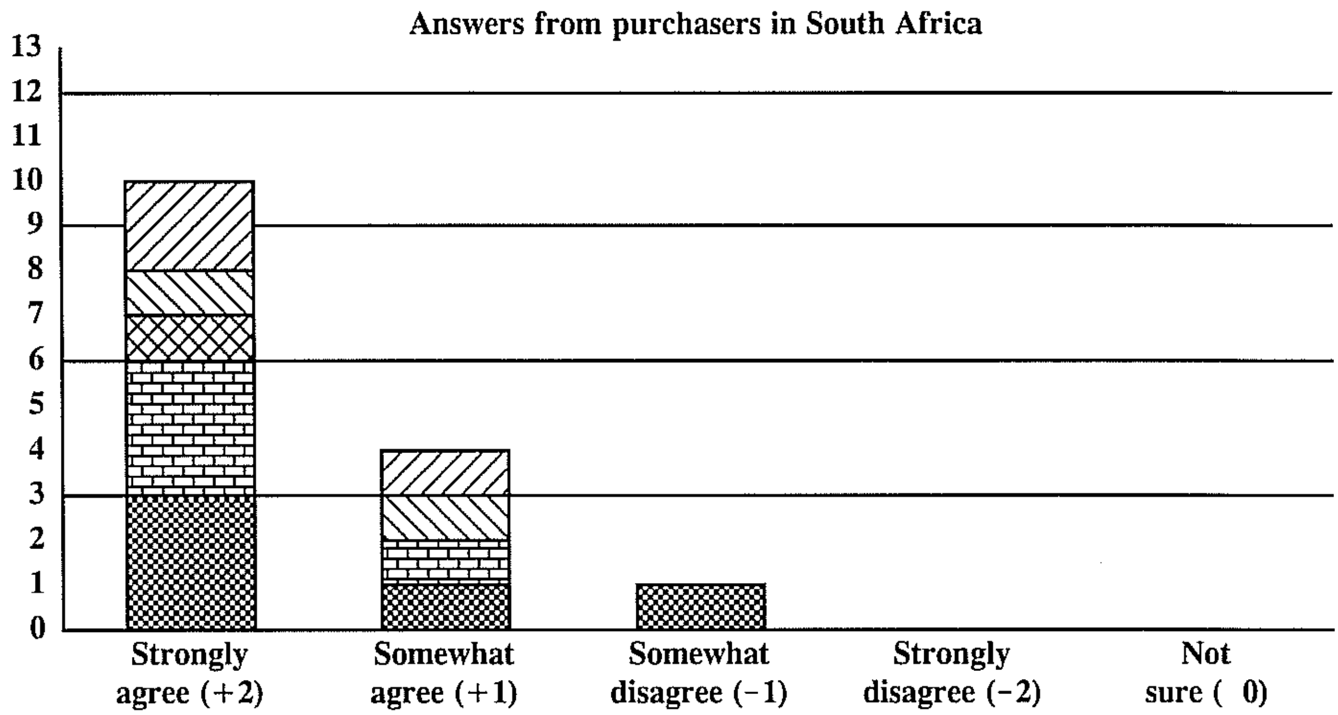
Sufficient institutional capacity within a community to care for the pump(s) on a day-to-day basis is essential for sustainable handpump installations.

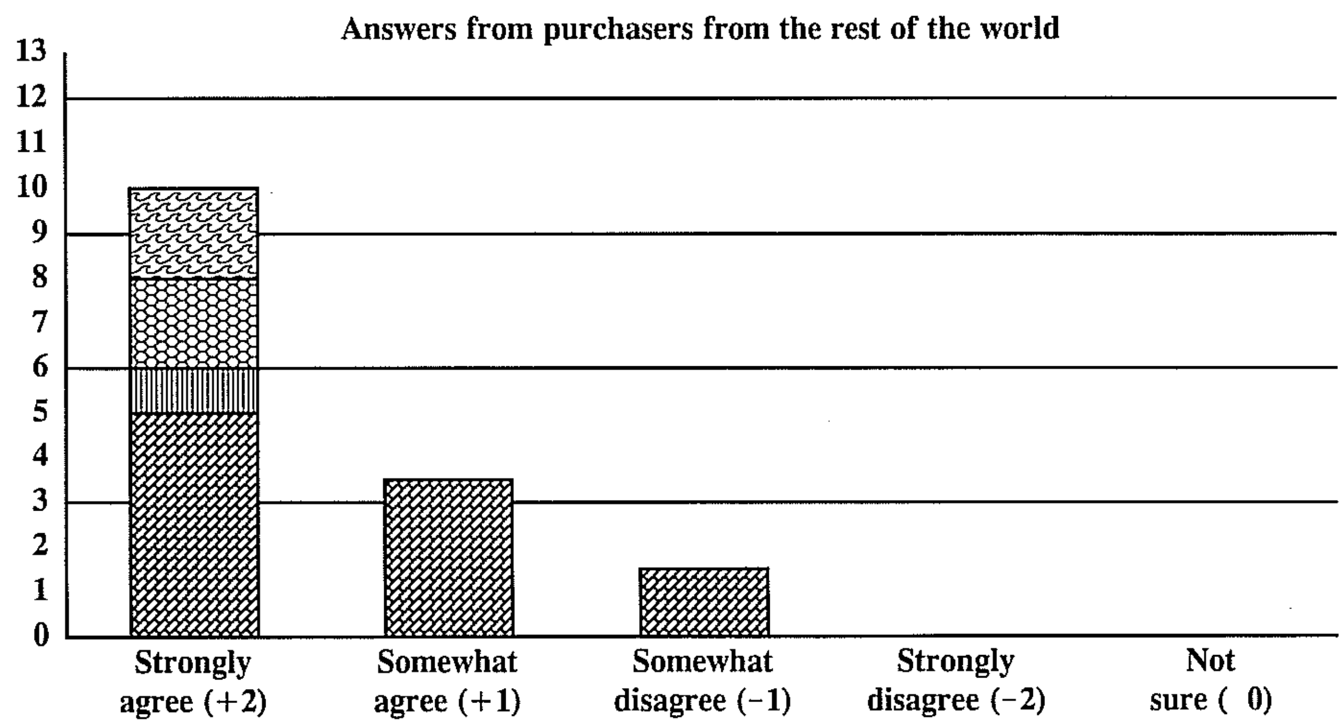




Handpump purchasers' survey: statement 9

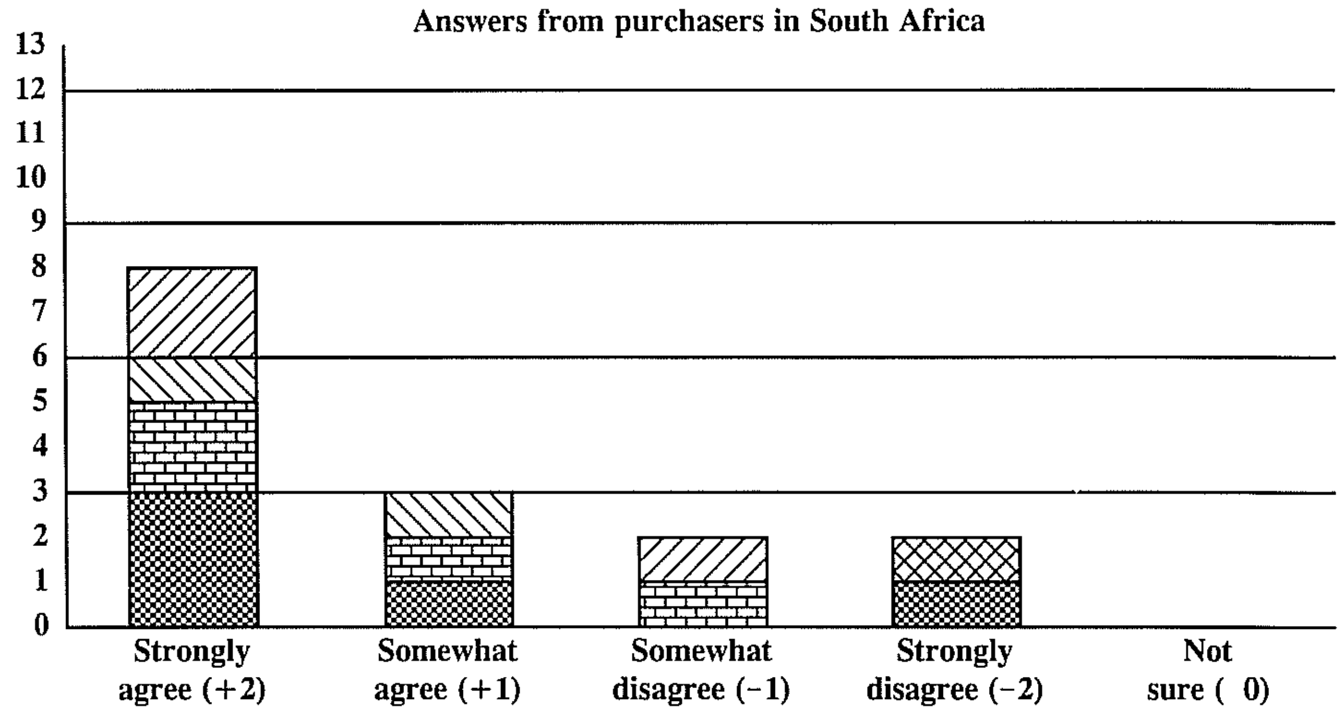
Sufficient institutional capacity within a community to manage cost recovery is essential for successful handpump installations.

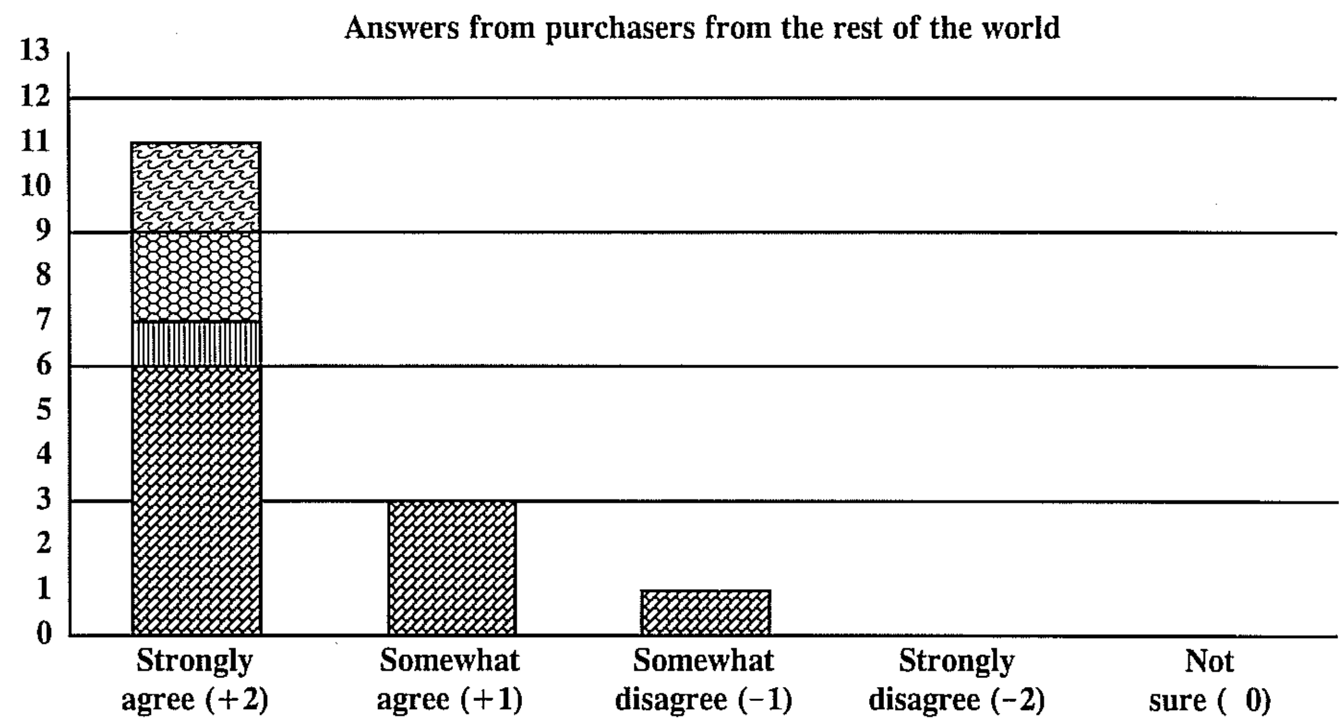




Handpump purchasers' survey: statement 10

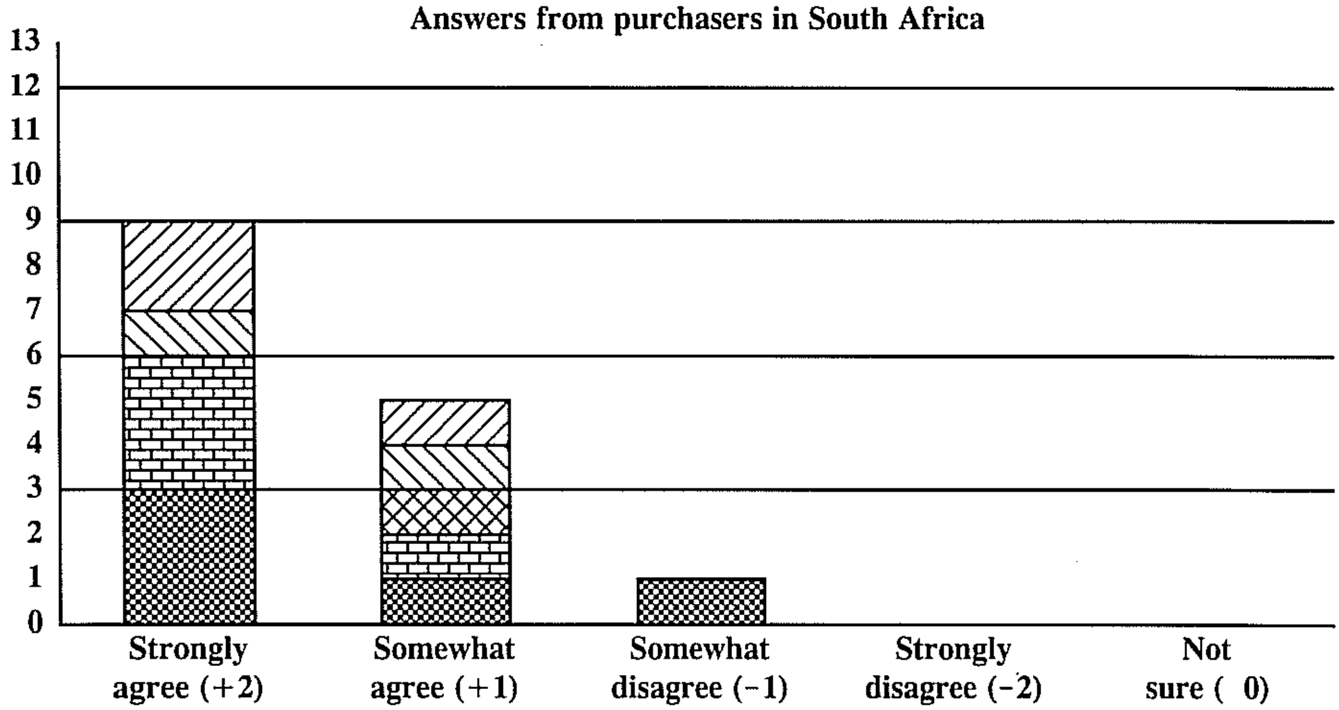
Before installing a handpump on a borehole, the yield of the borehole should be tested.

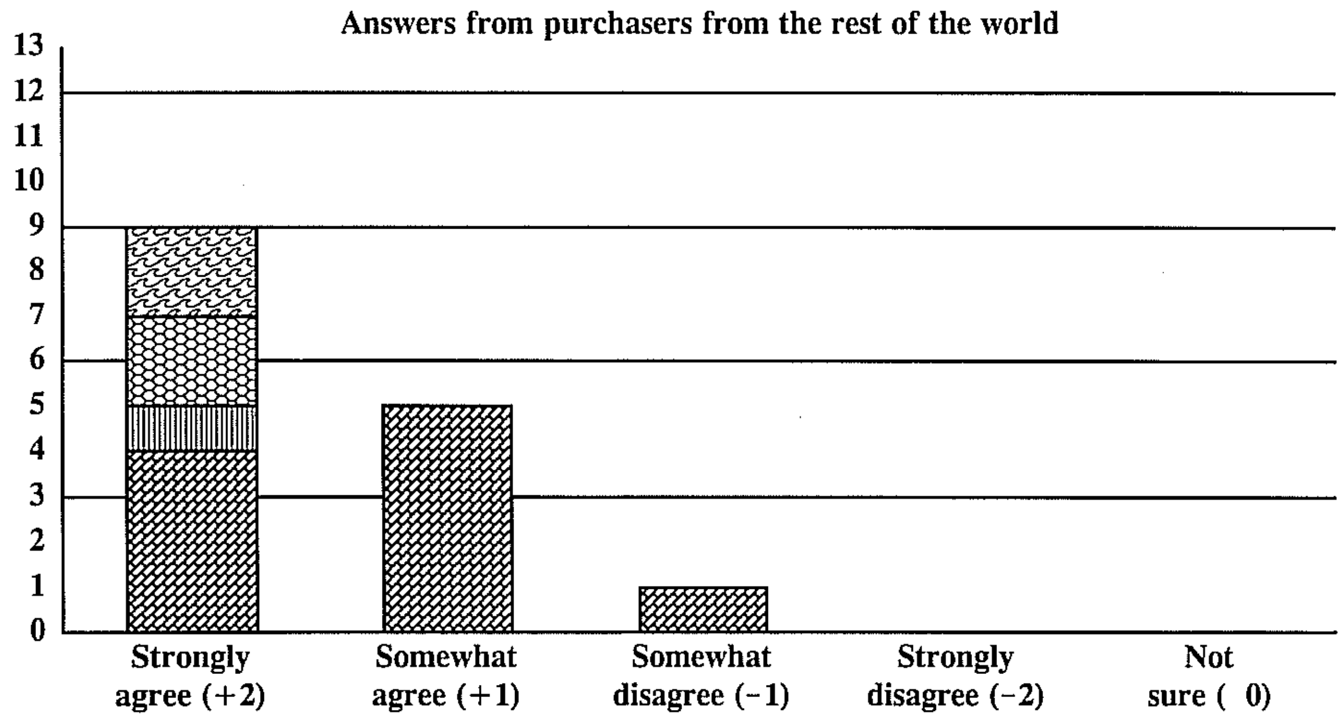




Handpump purchasers' survey: statement 11

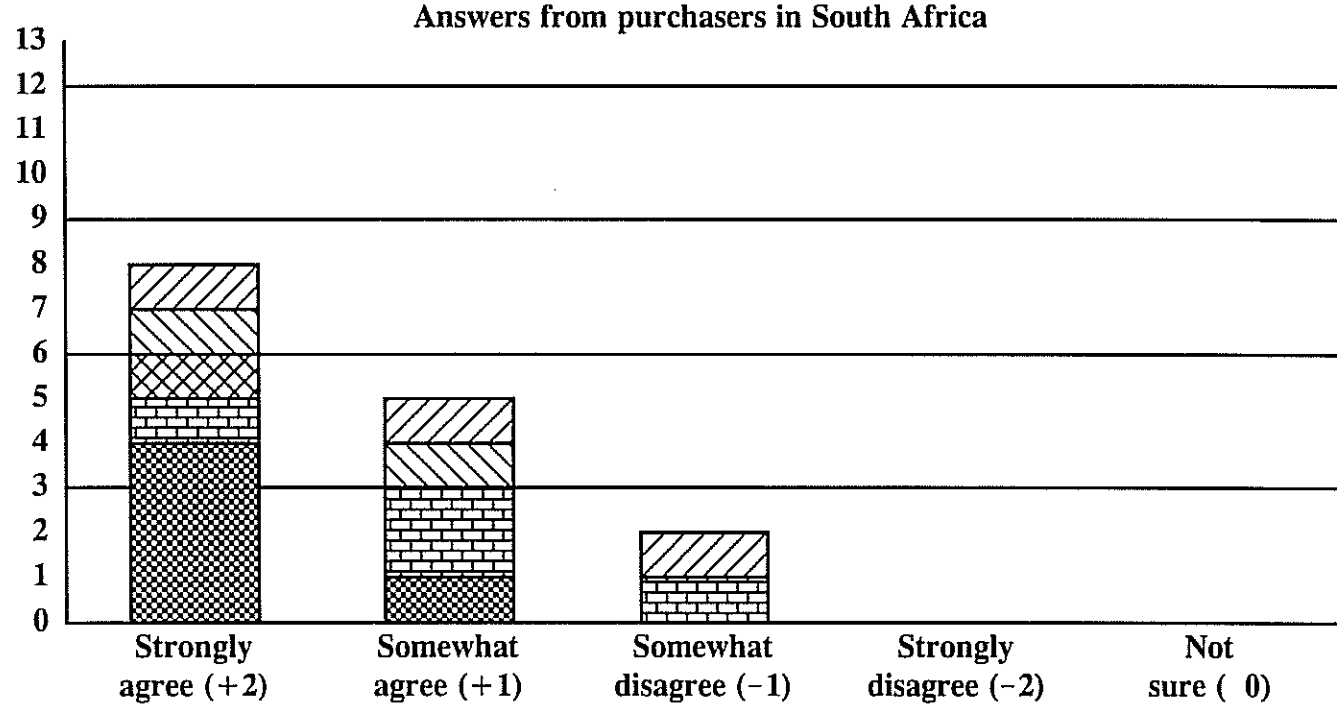
Before installing a handpump on a borehole, the quality of the water should be analysed.

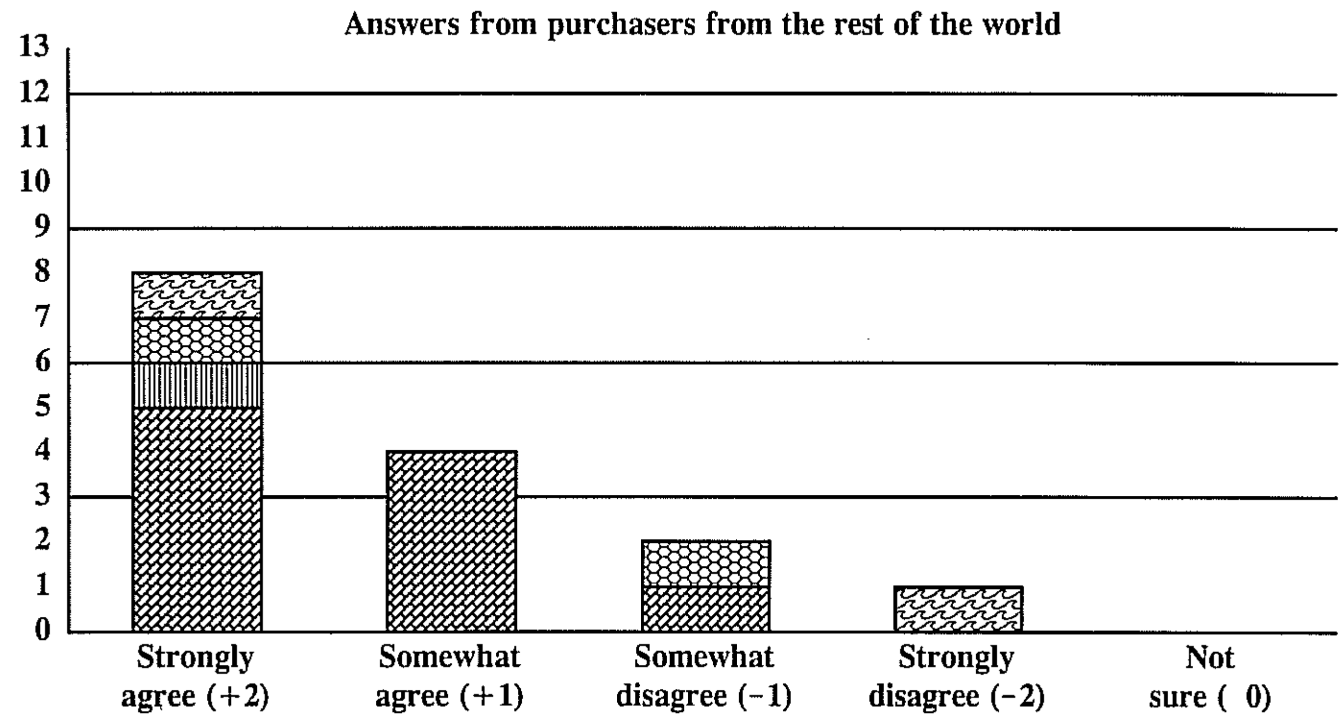




Handpump purchasers' survey: statement 12

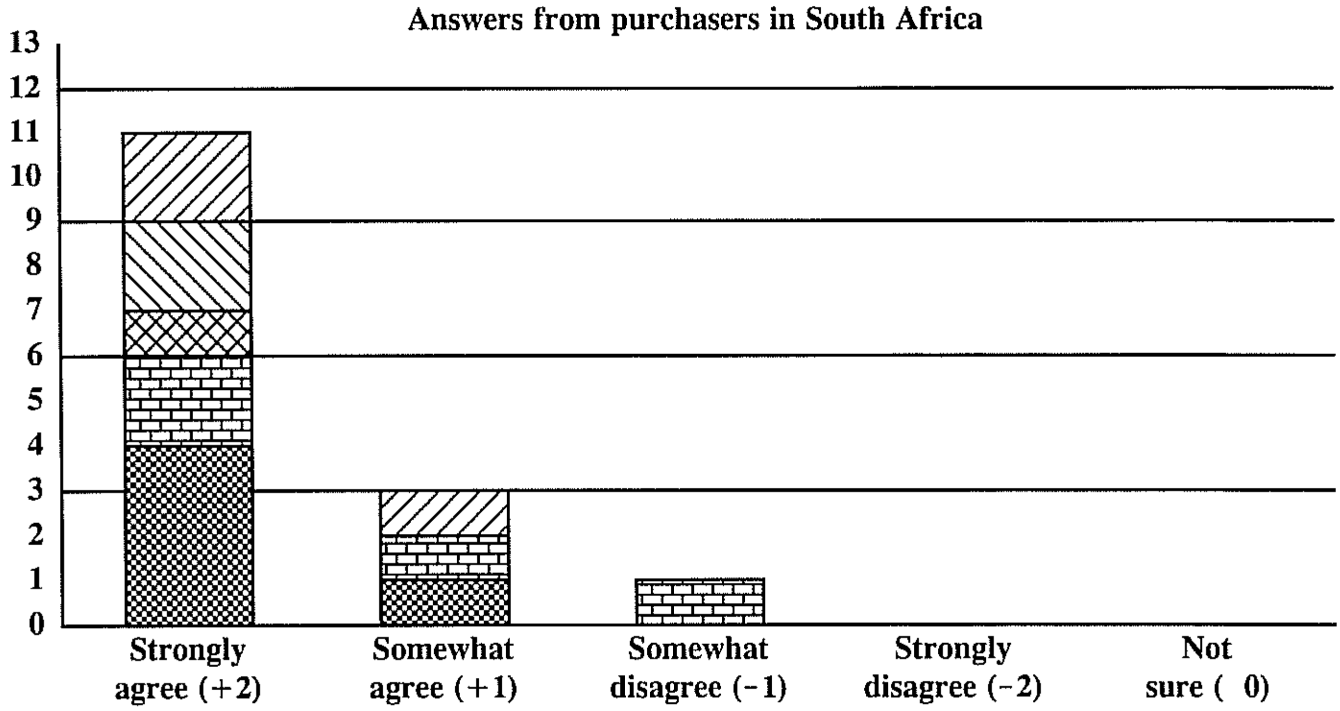
It is unreasonable to expect individual communities to be completely self-sufficient. It is therefore essential that any district in which handpumps are to be installed has an adequate repair network in operation.

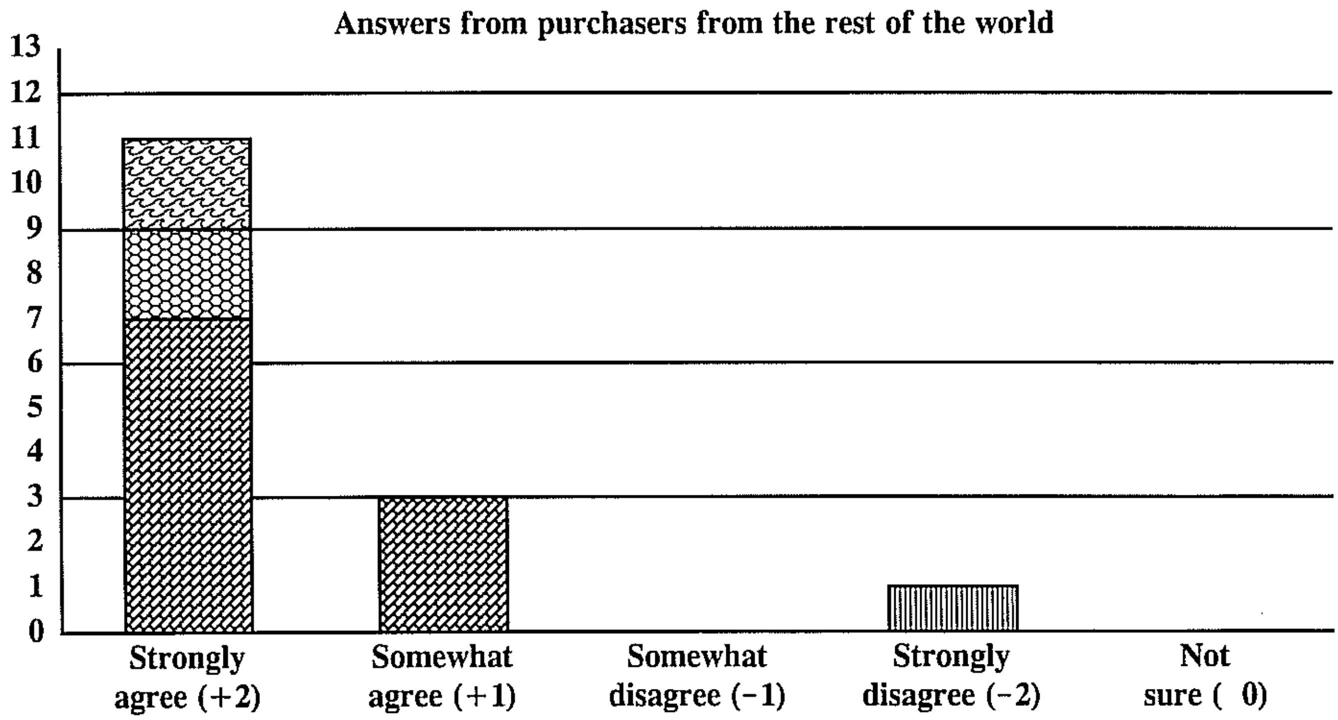




Handpump purchasers' survey: statement 13

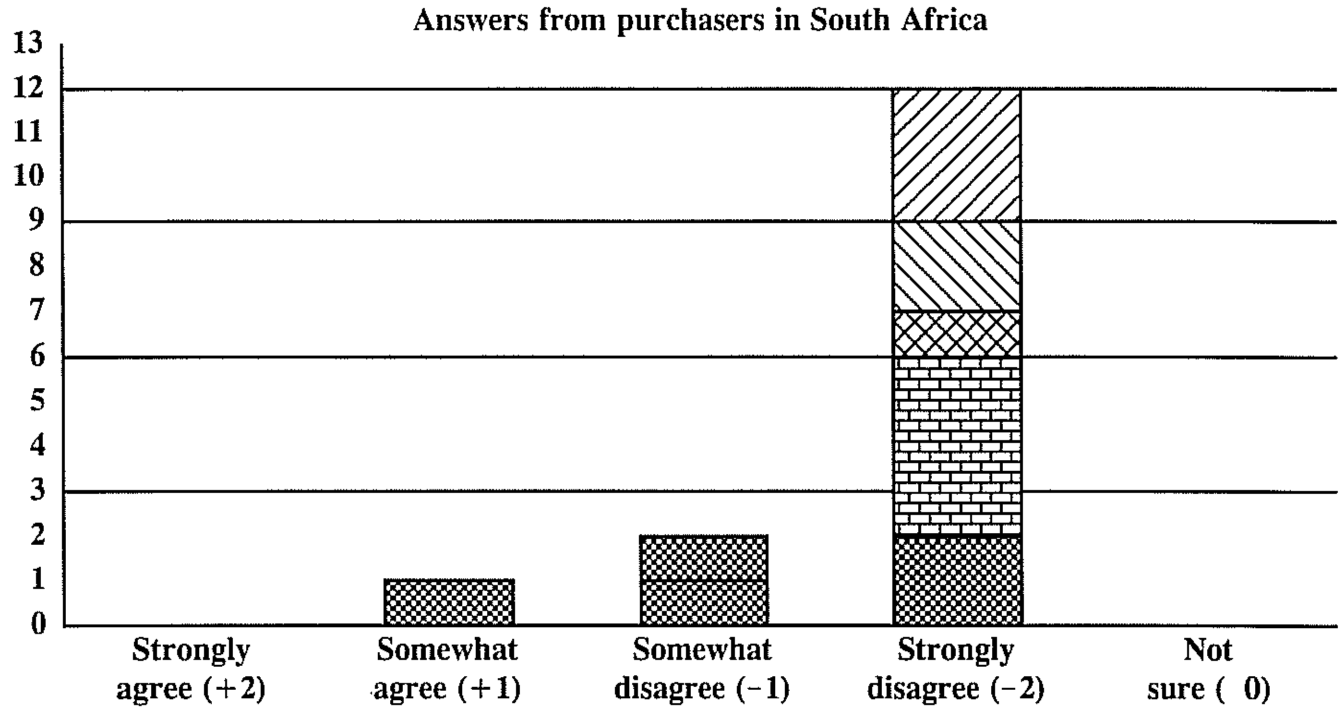
It is unreasonable to expect individual communities to be completely self-sufficient. It is therefore essential that any district in which handpumps are to be installed has an adequate spares network in operation.

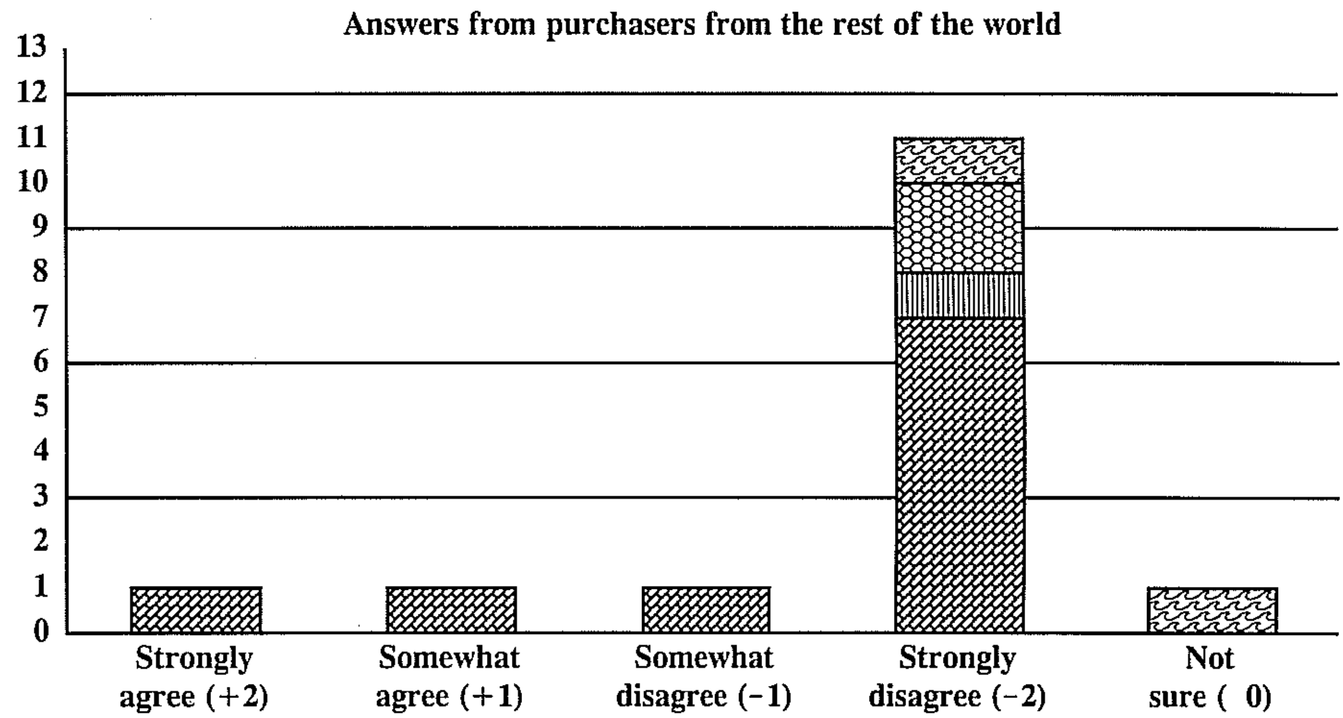




Handpump purchasers' survey: statement 14

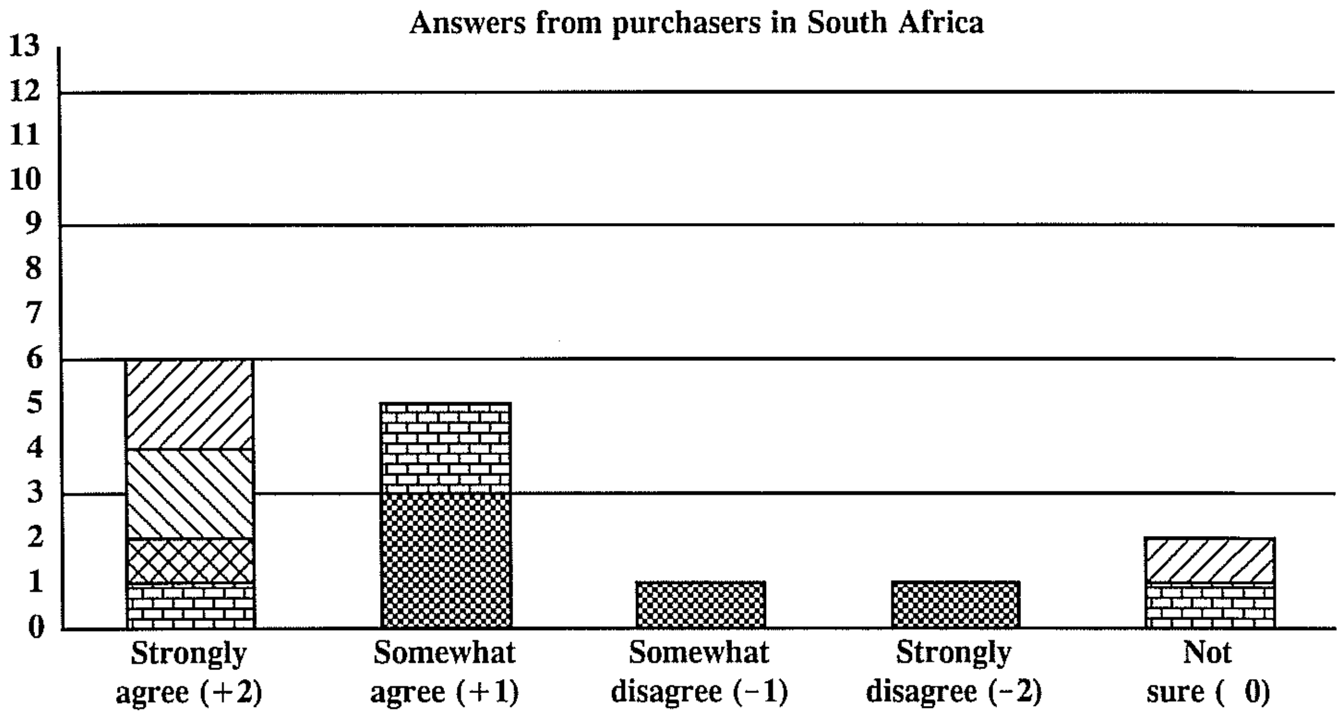
Community water supply schemes are a waste of good money. Only large centralised bulk schemes result in reliable rural water supplies.

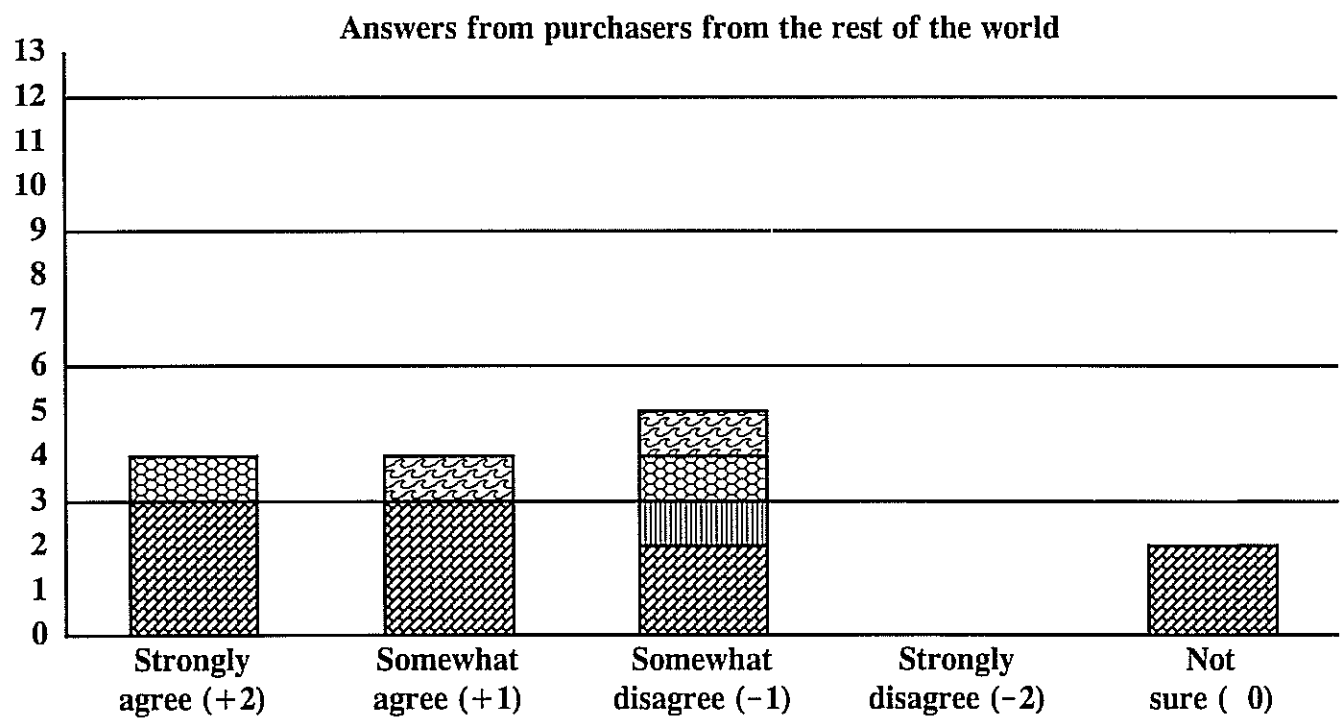




Handpump purchasers' survey: statement 15

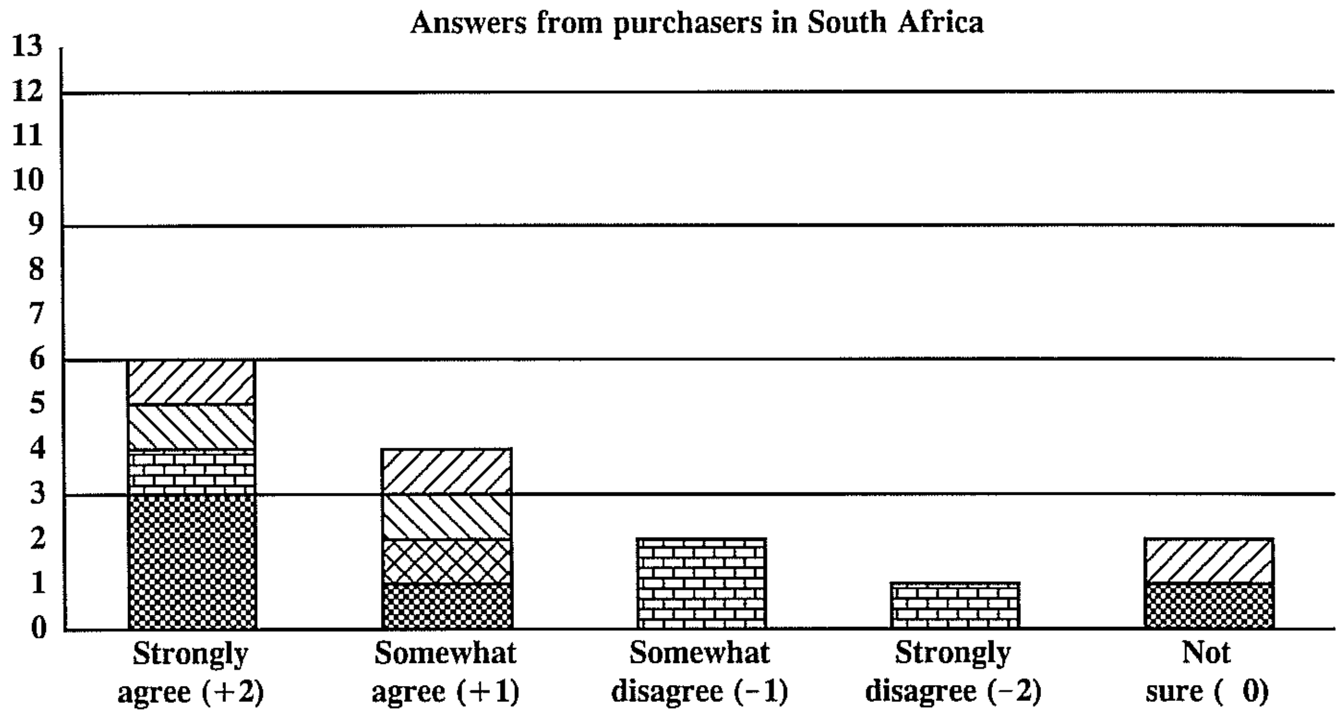
Handpump installations should be carried out in a manner that allows the level of the water to be checked whilst the pump is still in the hole.

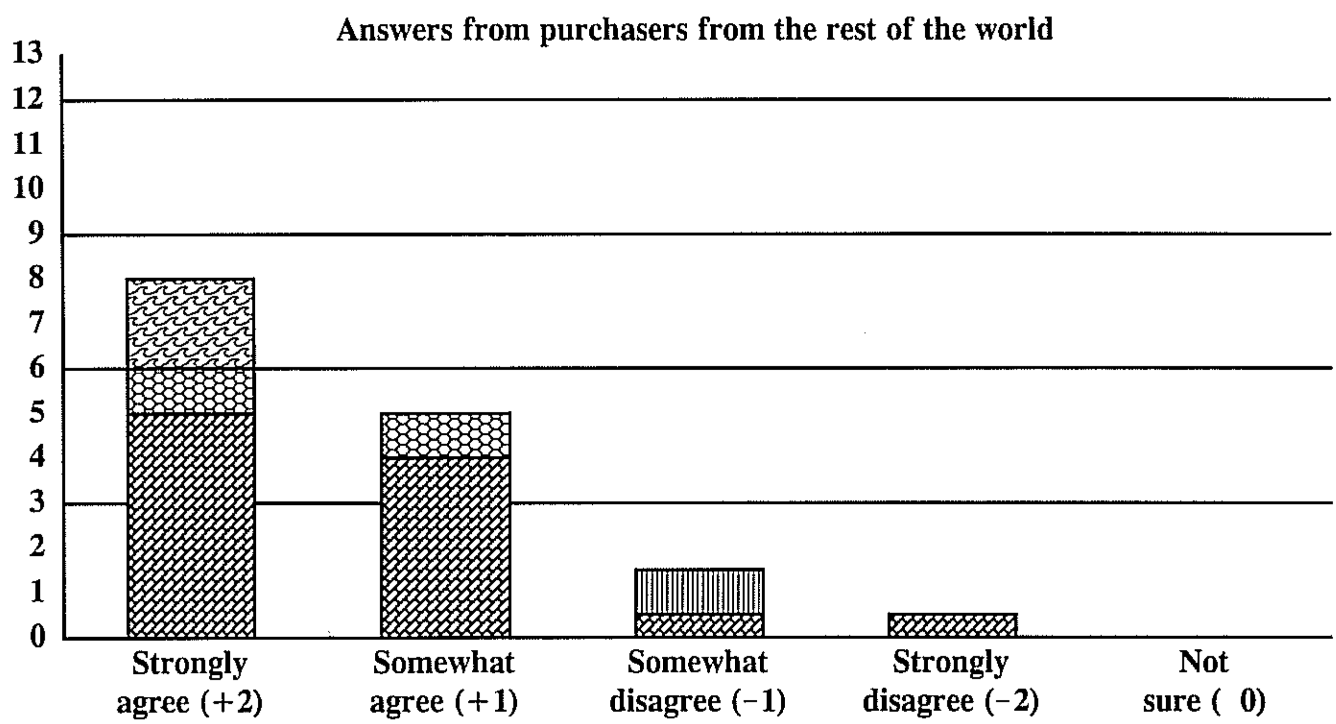




Handpump purchasers' survey: statement 16

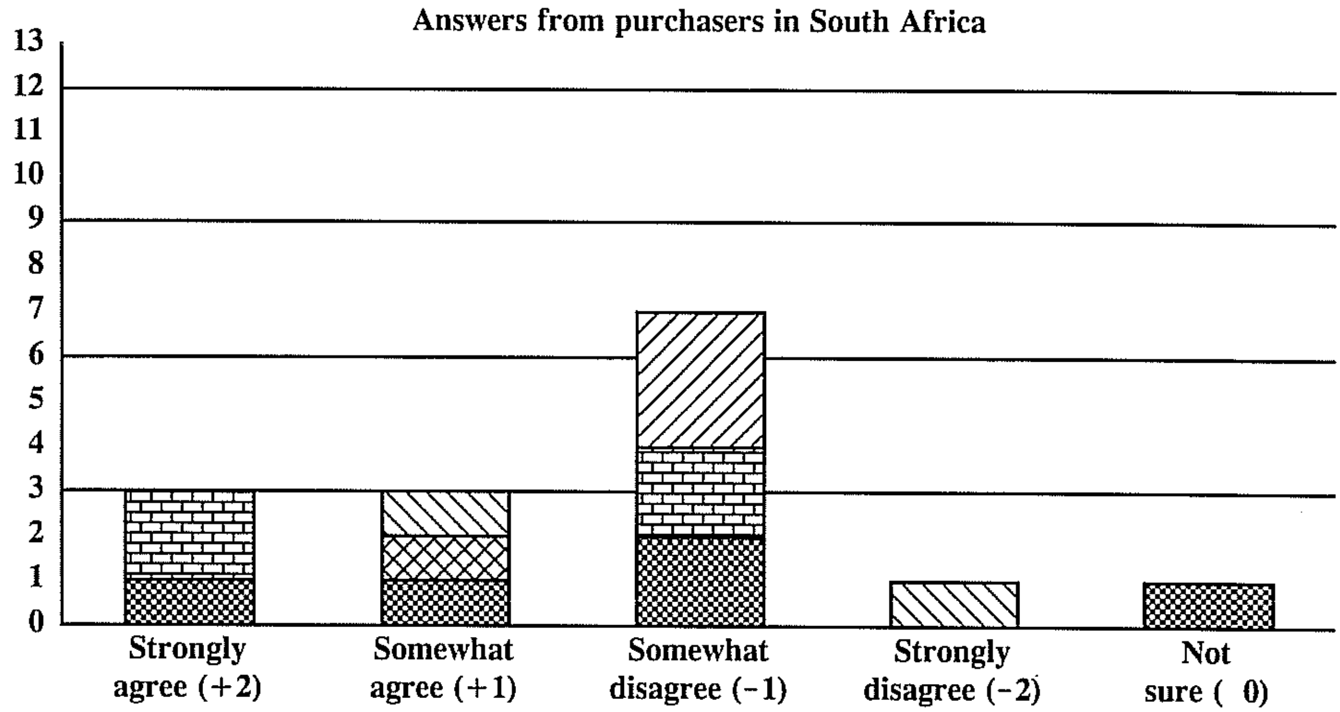
Being lighter and easier to handle, plastic riser pipes are ideal for community handpumps and should be used more widely.

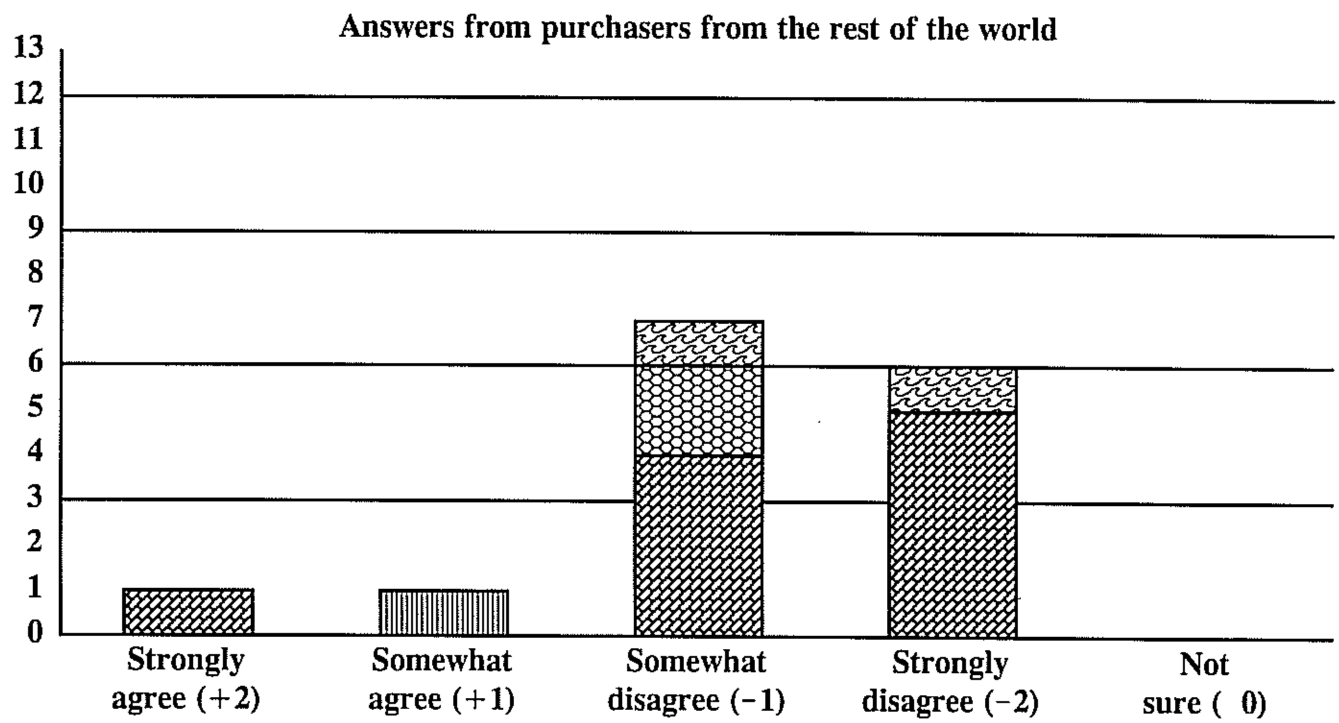




Handpump purchasers' survey: statement 17

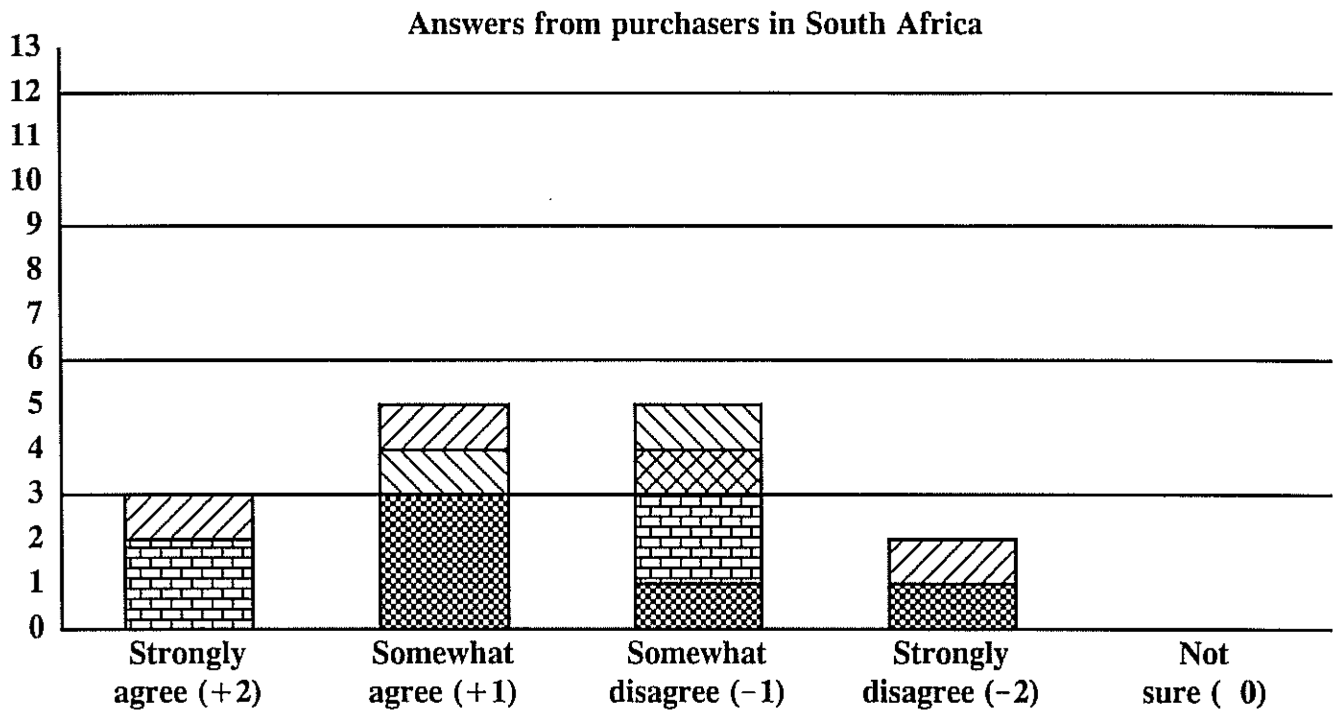
Because of problems with joining and general reliability, plastic riser pipes should only be considered when corrosion is a problem.

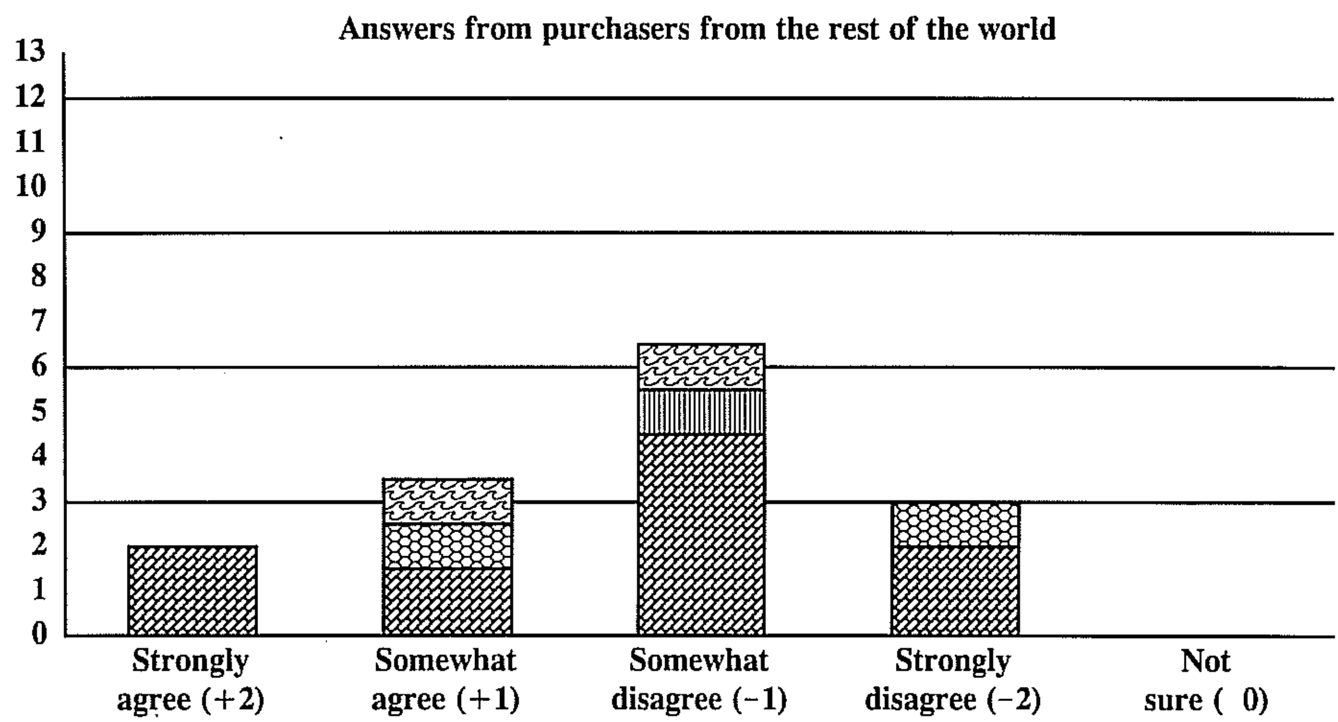




Handpump purchasers' survey: statement 18

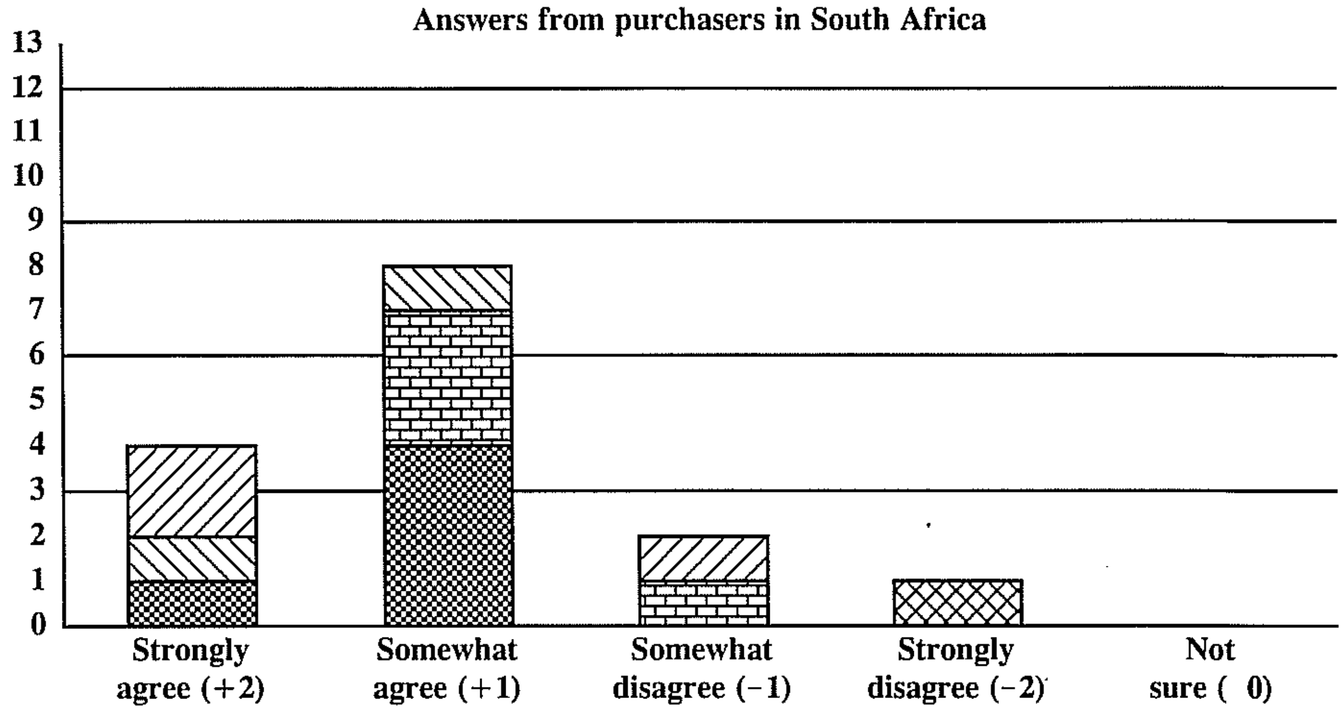
Communities generally do not favour handpumps because they have to walk long distances to collect their water.

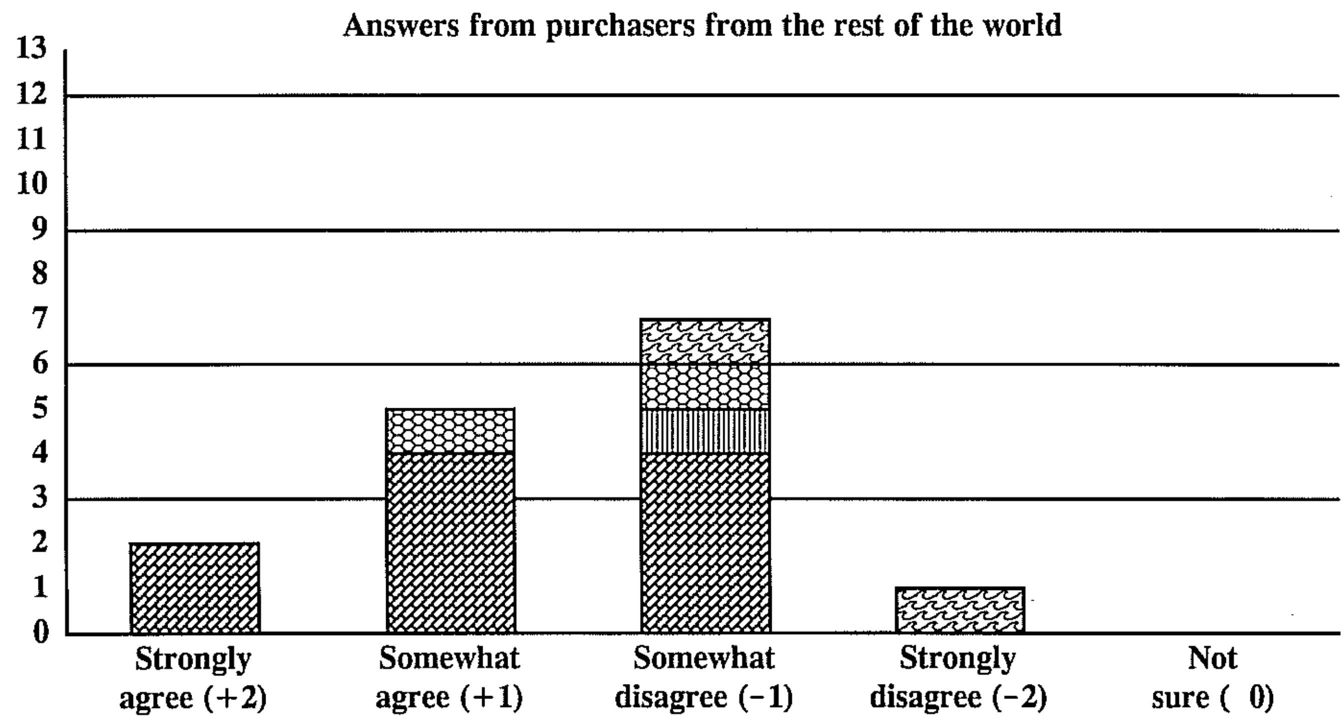




Handpump purchasers' survey: statement 19

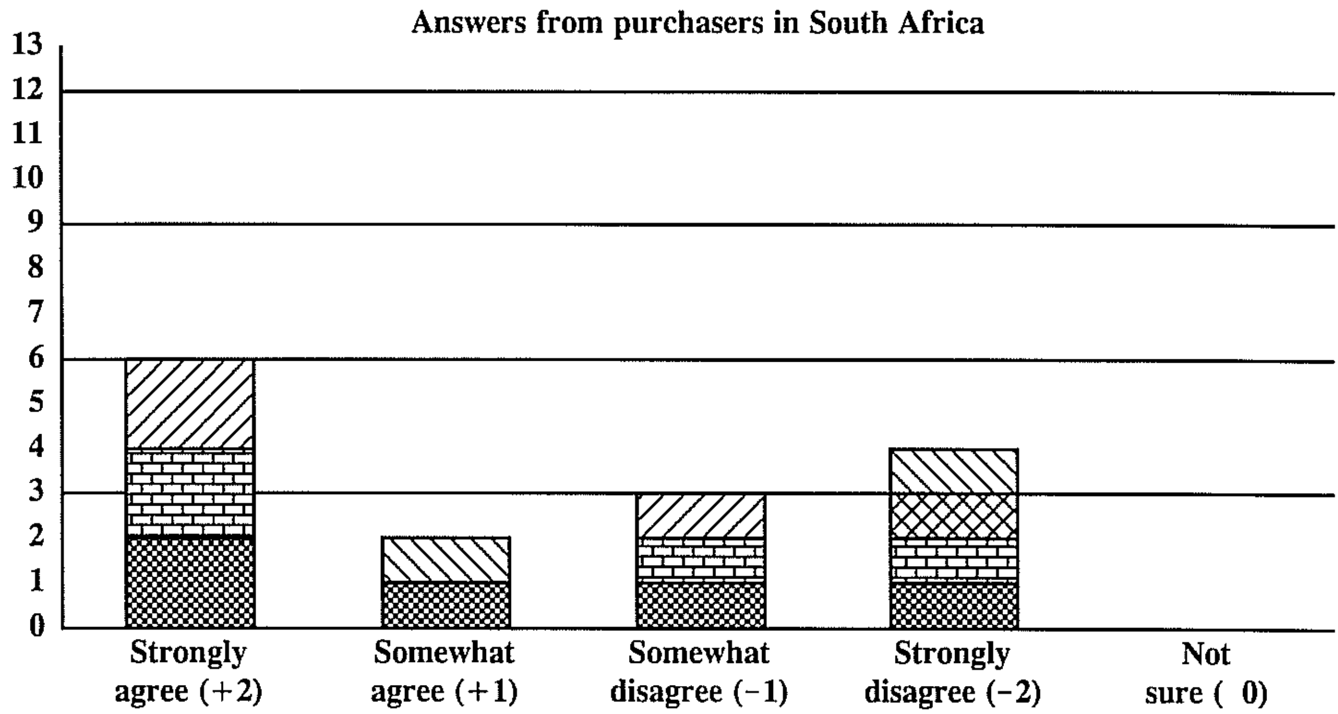
Communities generally do not favour handpumps because they experience handpumps as being unreliable.

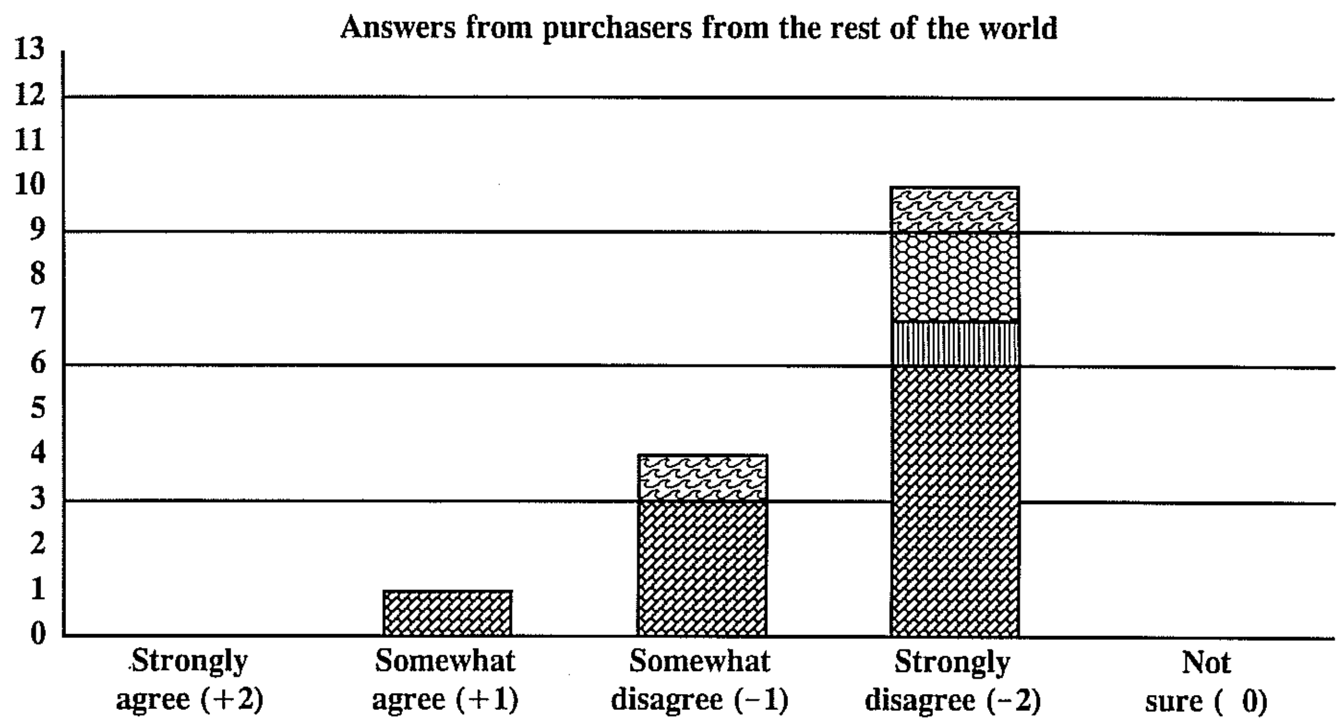




Handpump purchasers' survey: statement 20

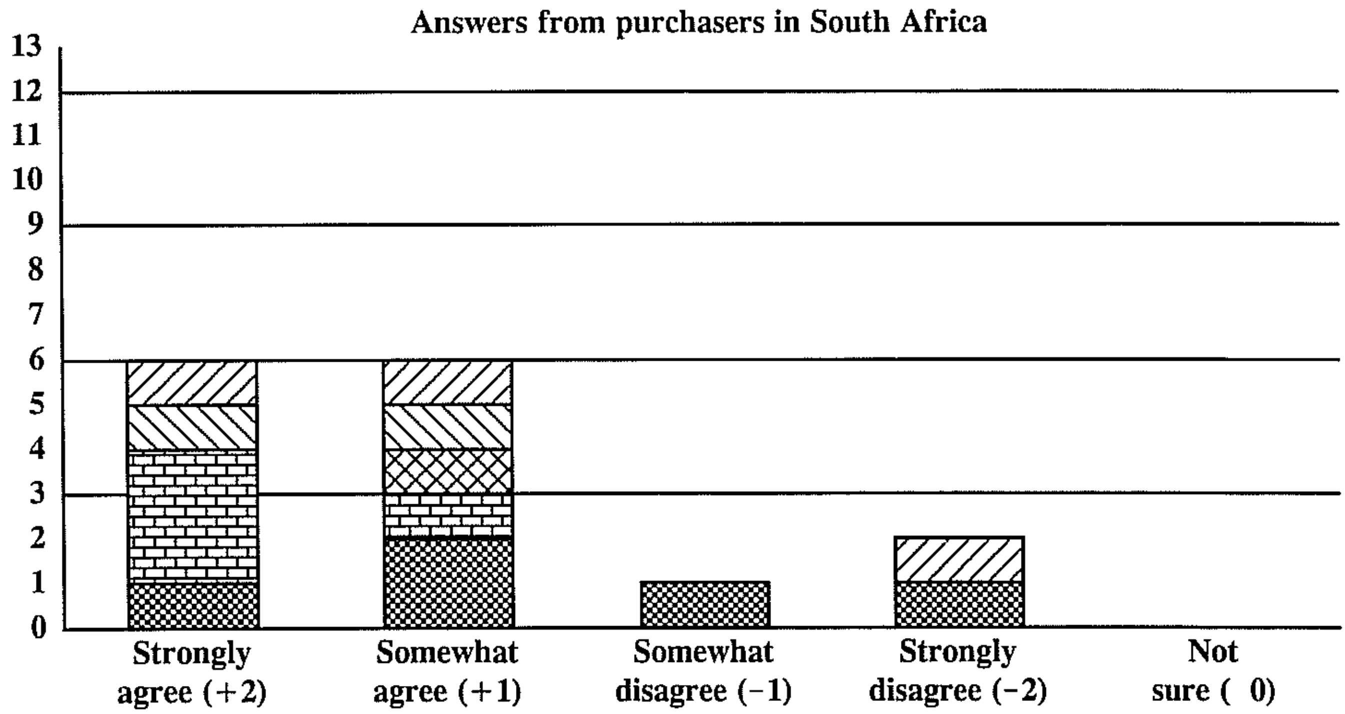
Handpumps are only useful as a back-up supply when other supplies fail.

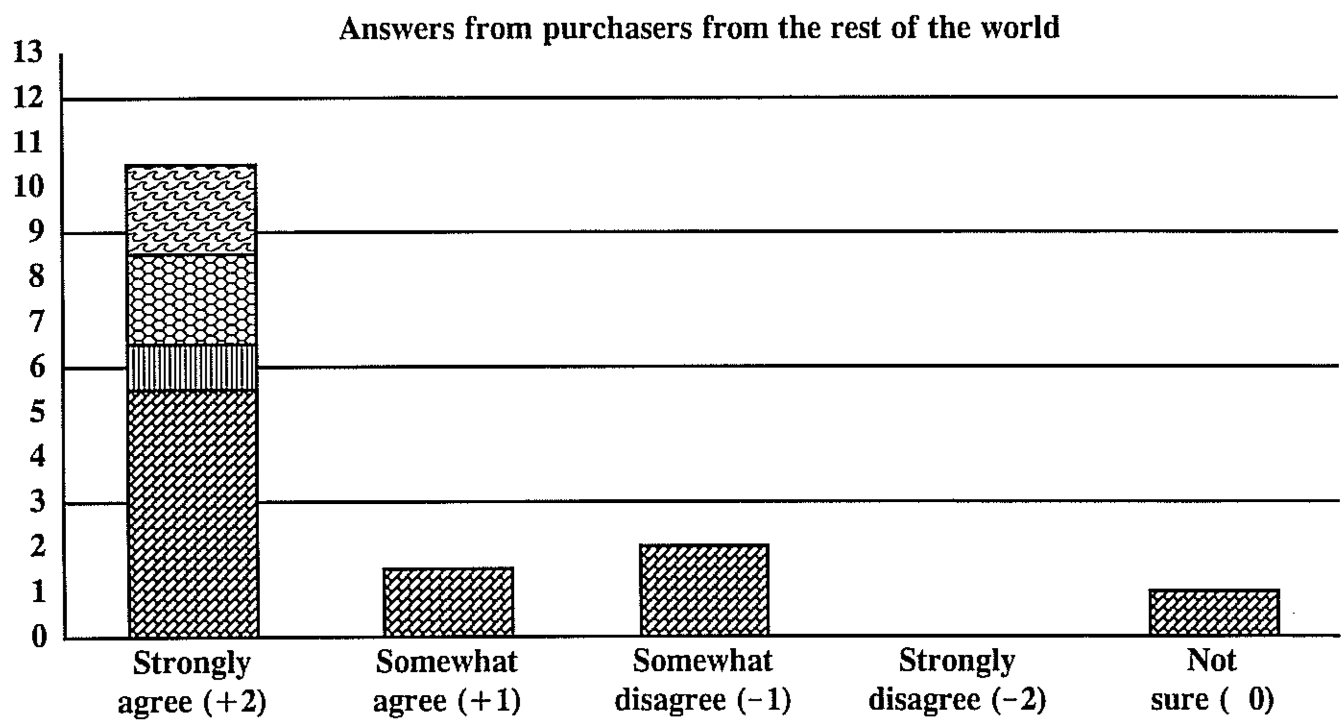




Handpump purchasers' survey: statement 21

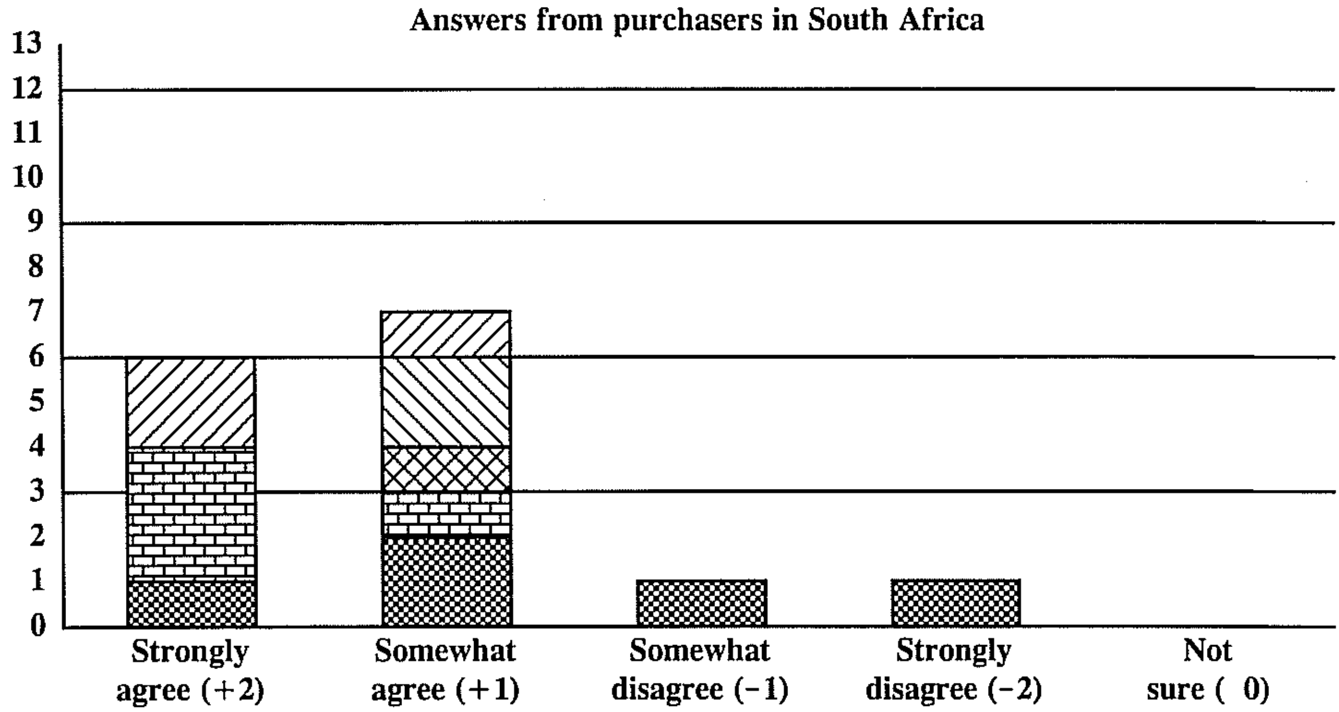
We must standardise on one or two pumps in a given area.

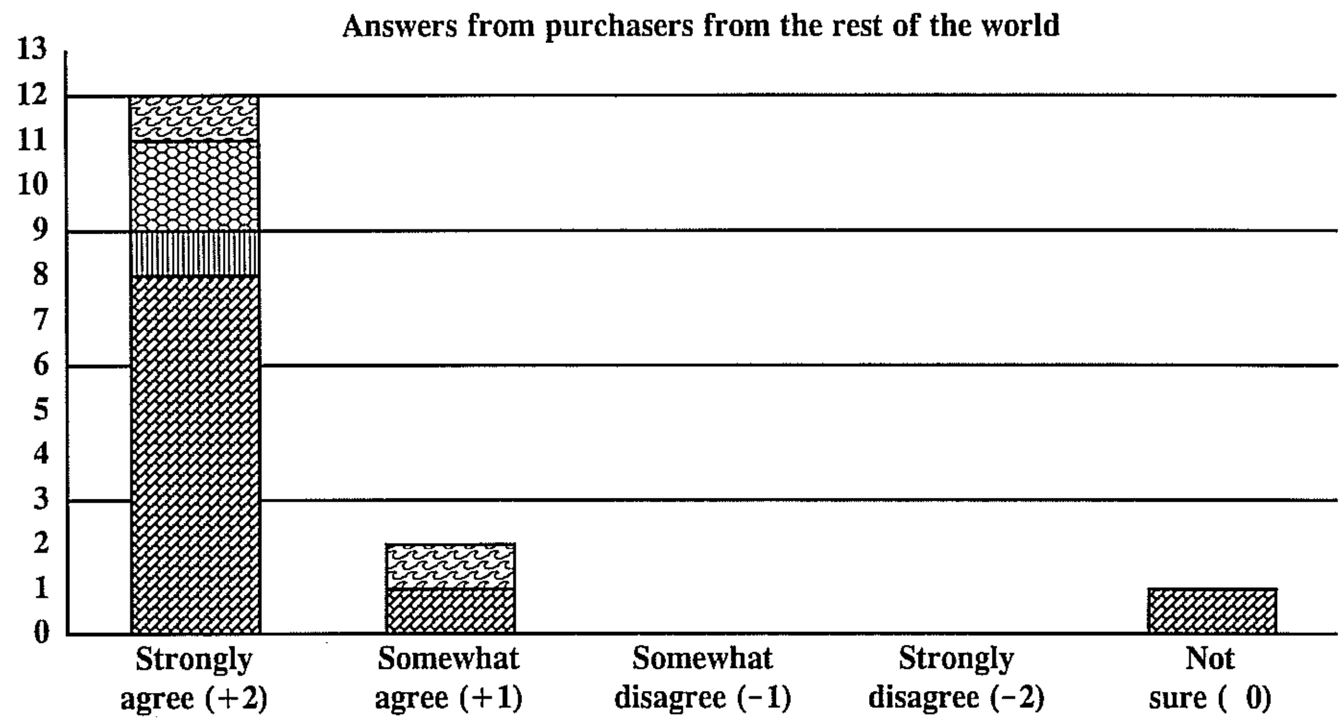




Handpump purchasers' survey: statement 22

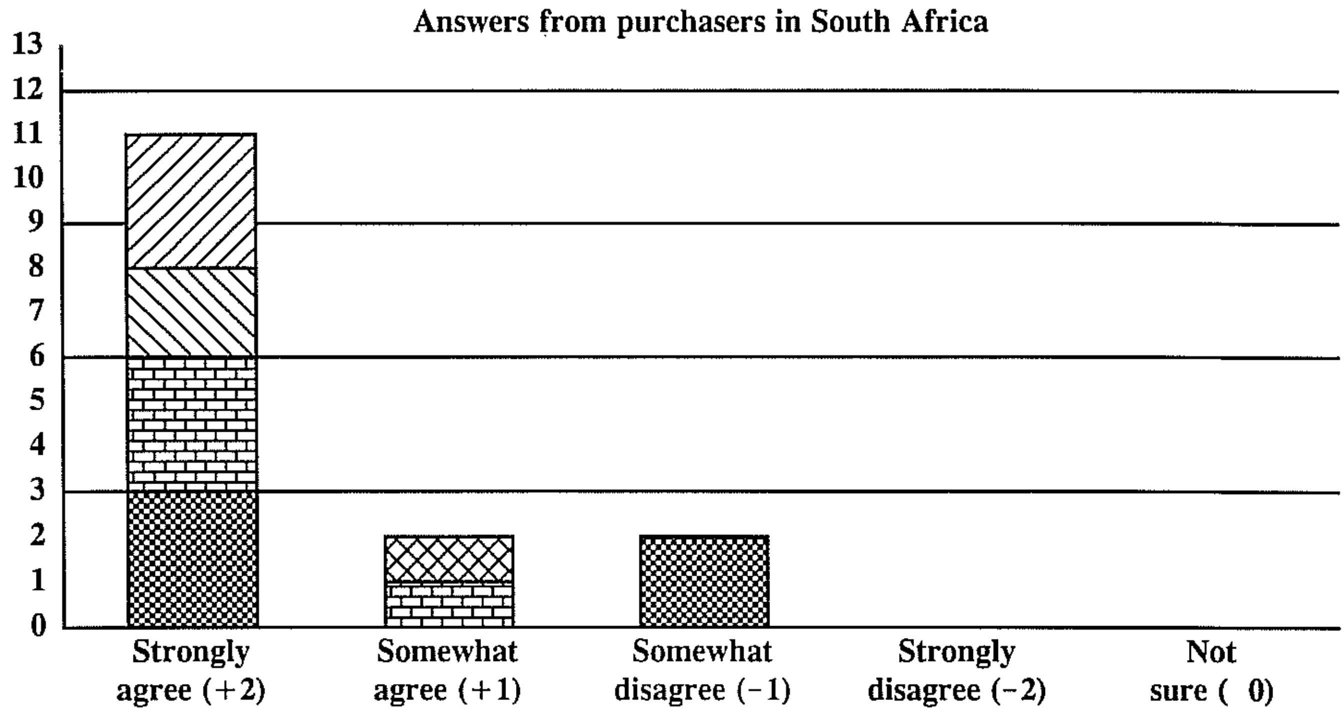
Pumps must be purchased to a strict specification.

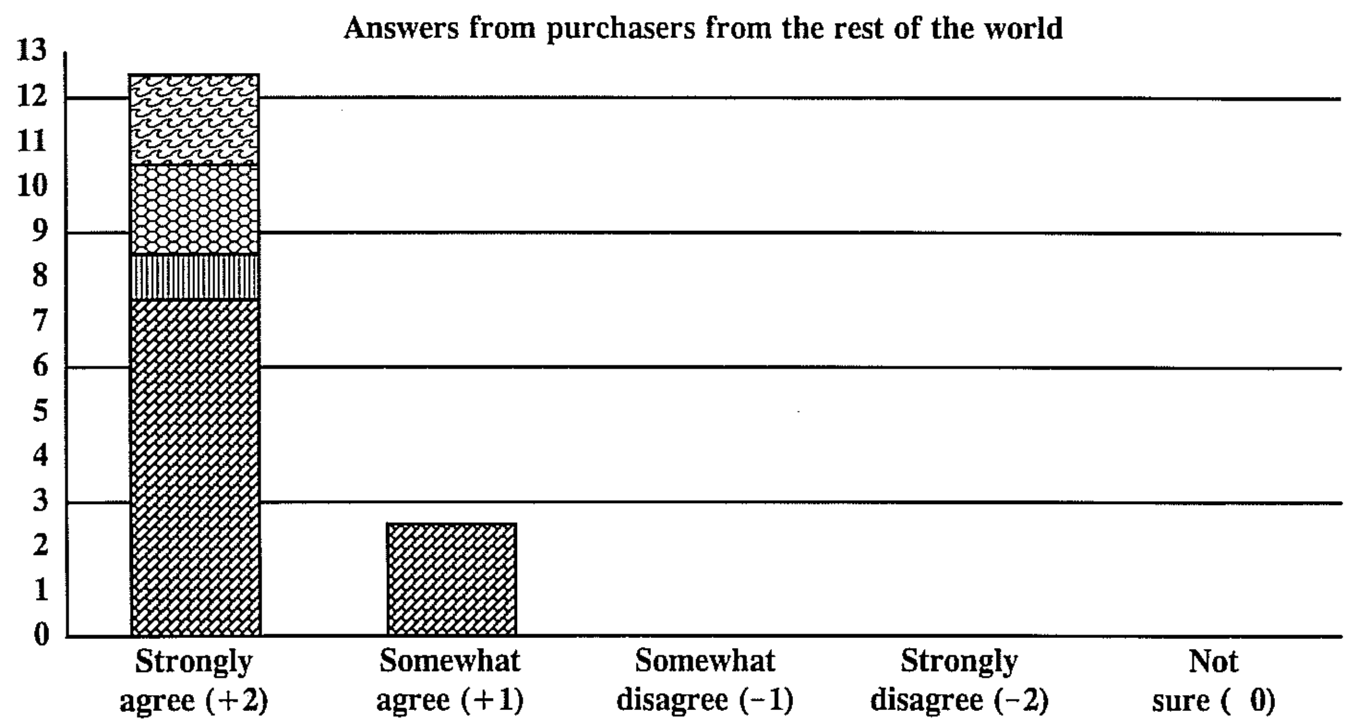




Handpump purchasers' survey: statement 23

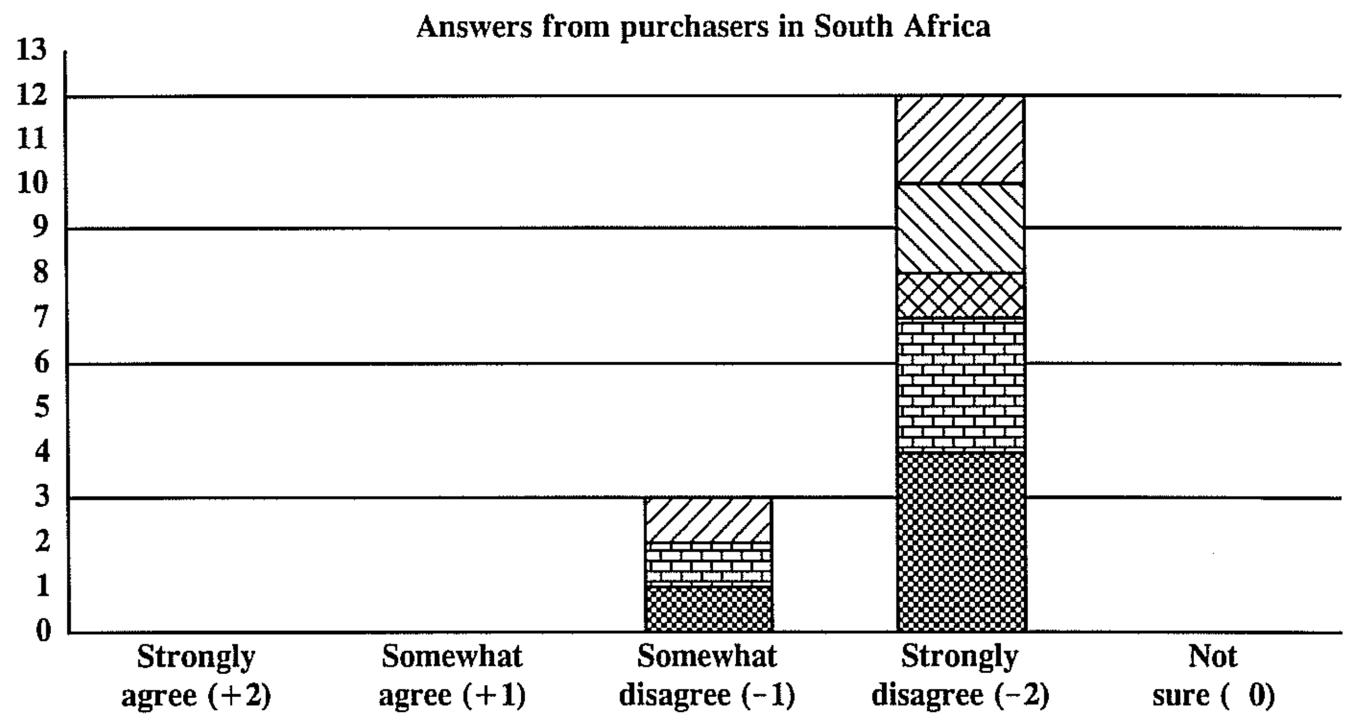
Pumps must be designed to facilitate community level maintenance.

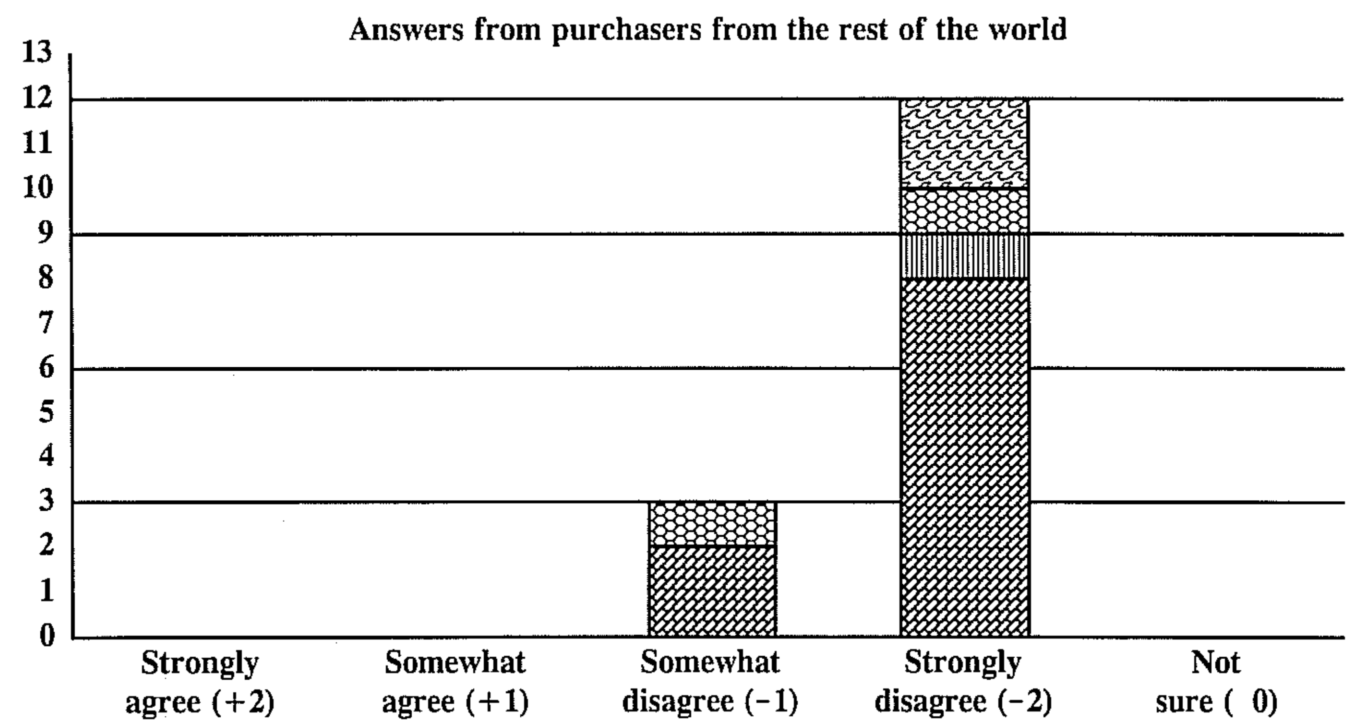




Handpump purchasers' survey: statement 24

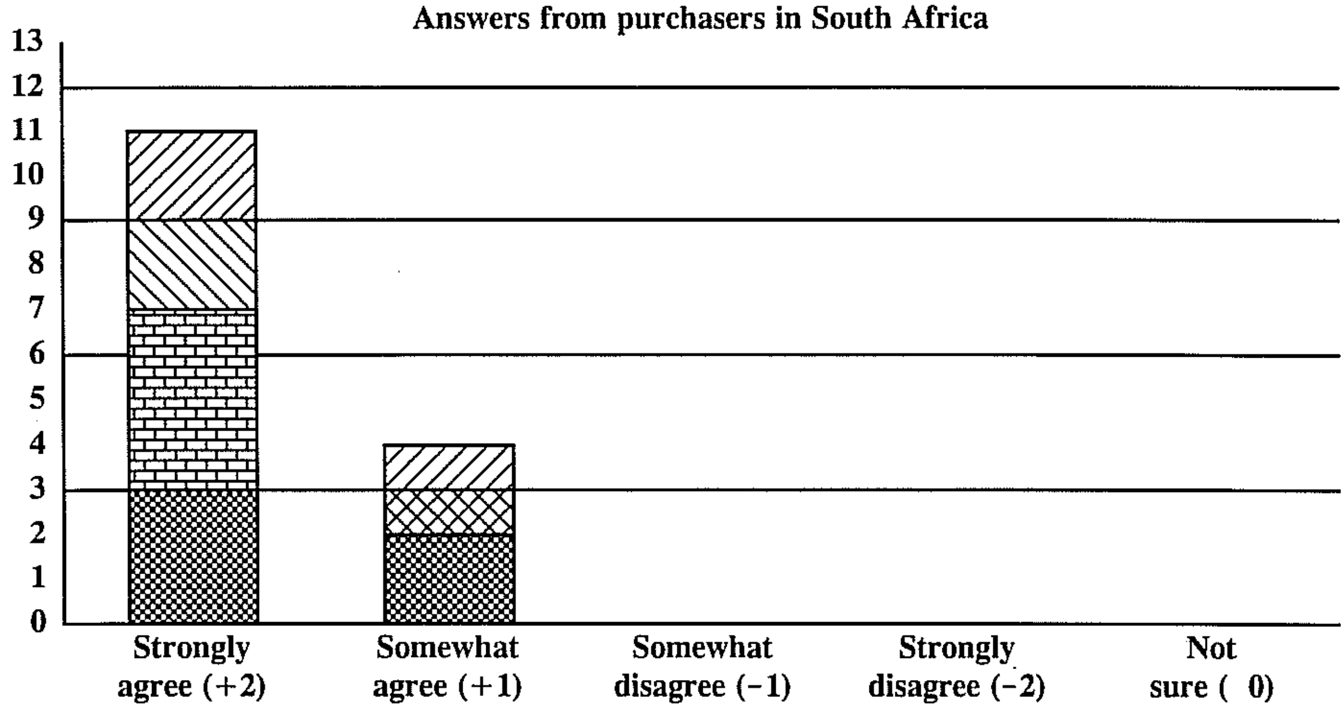
Purchasers should use price as the sole criteria to decide which pump to purchase.

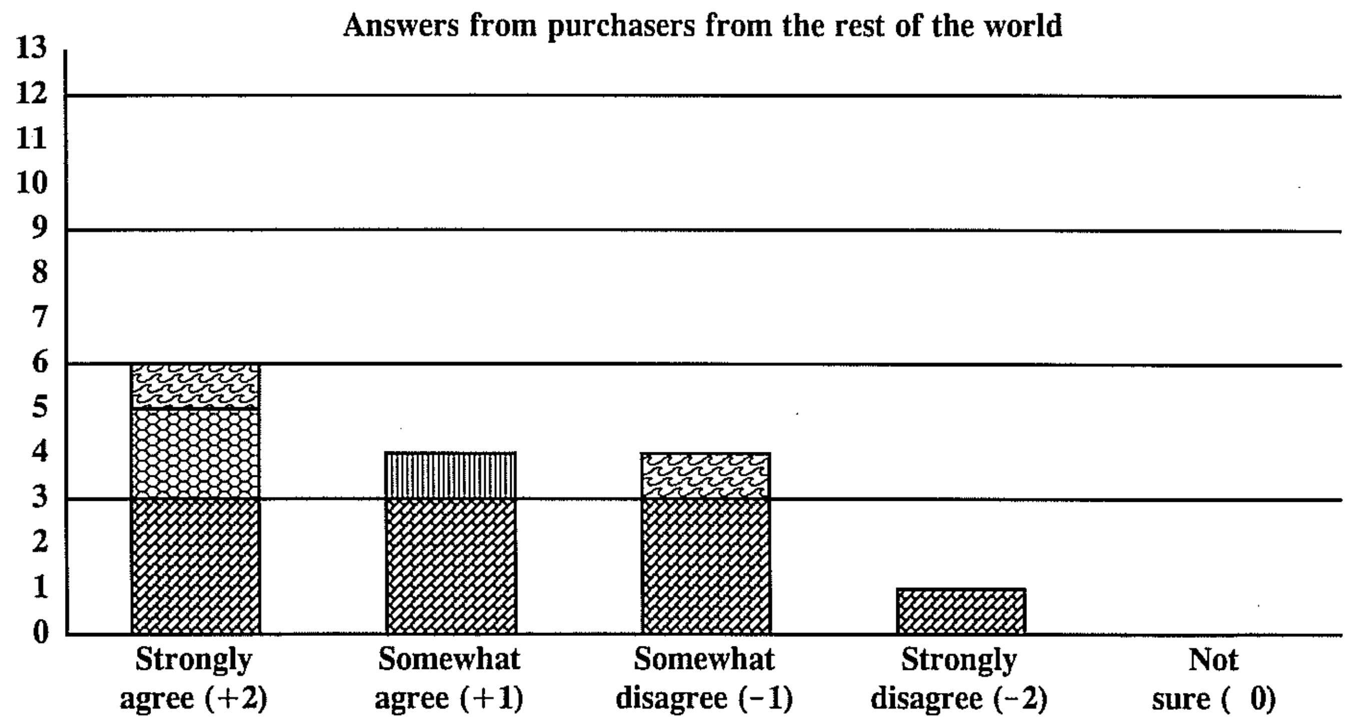




Handpump purchasers' survey: statement 25

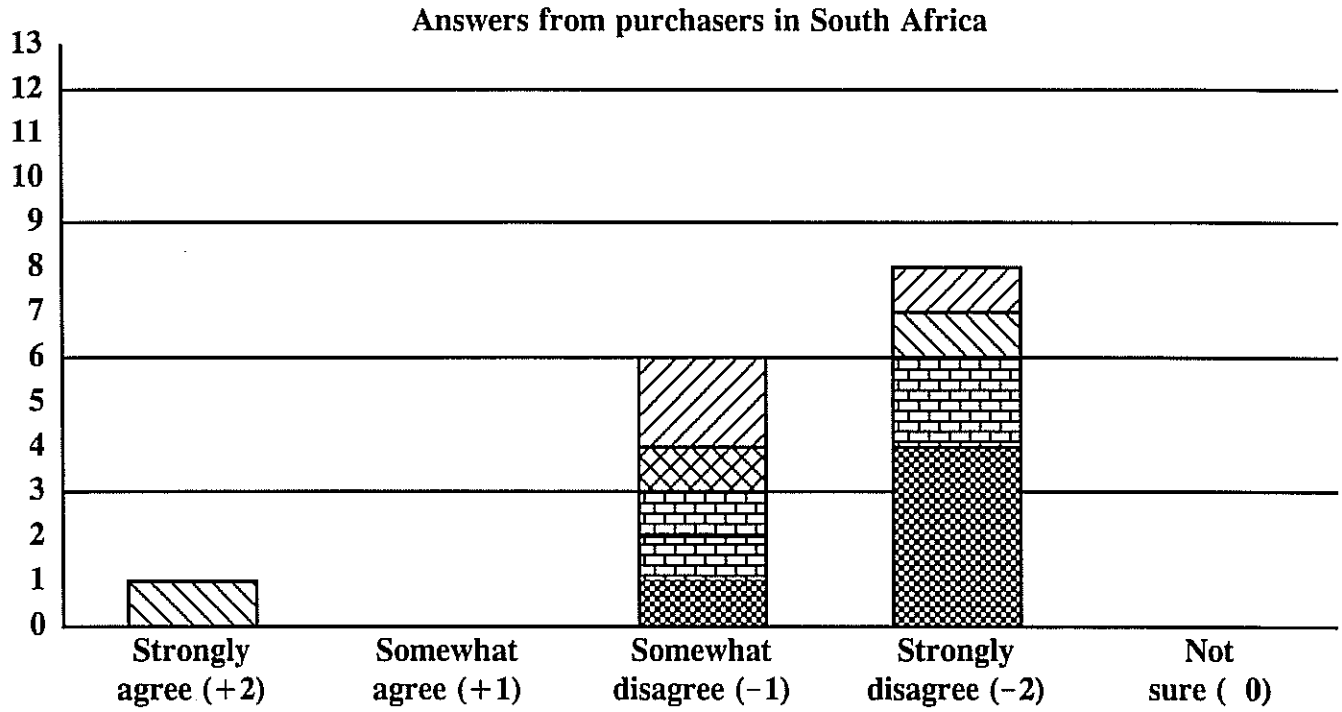
The back-up service provided by the pump seller is an essential criteria to be considered when purchasing a handpump.

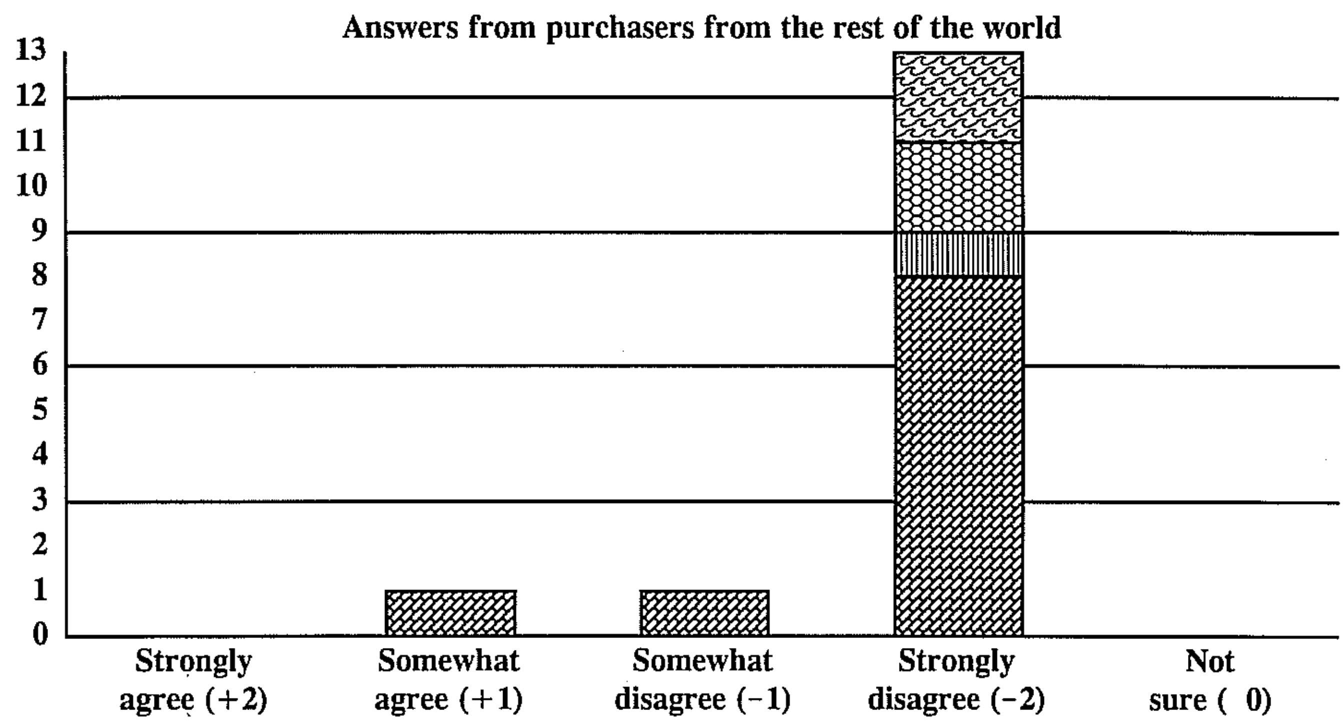




Handpump purchasers' survey: statement 26

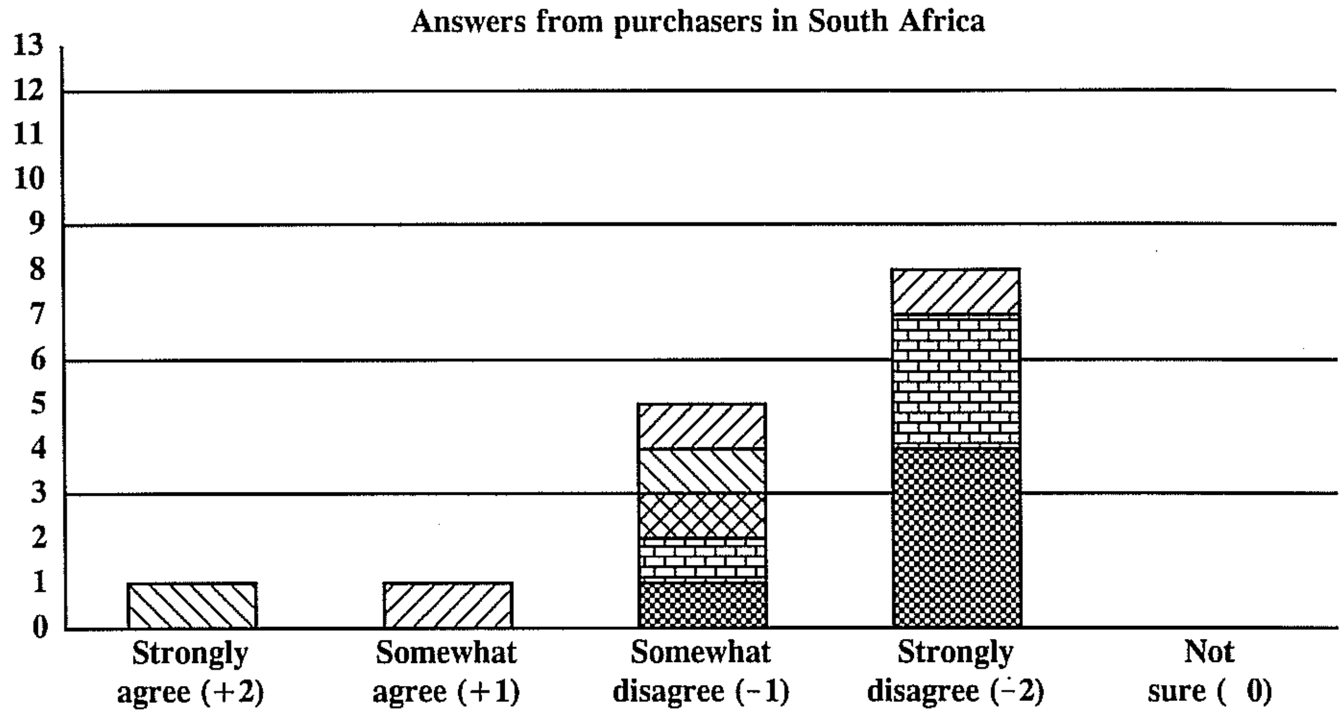
Pump corrosion can be ignored when purchasing a handpump.

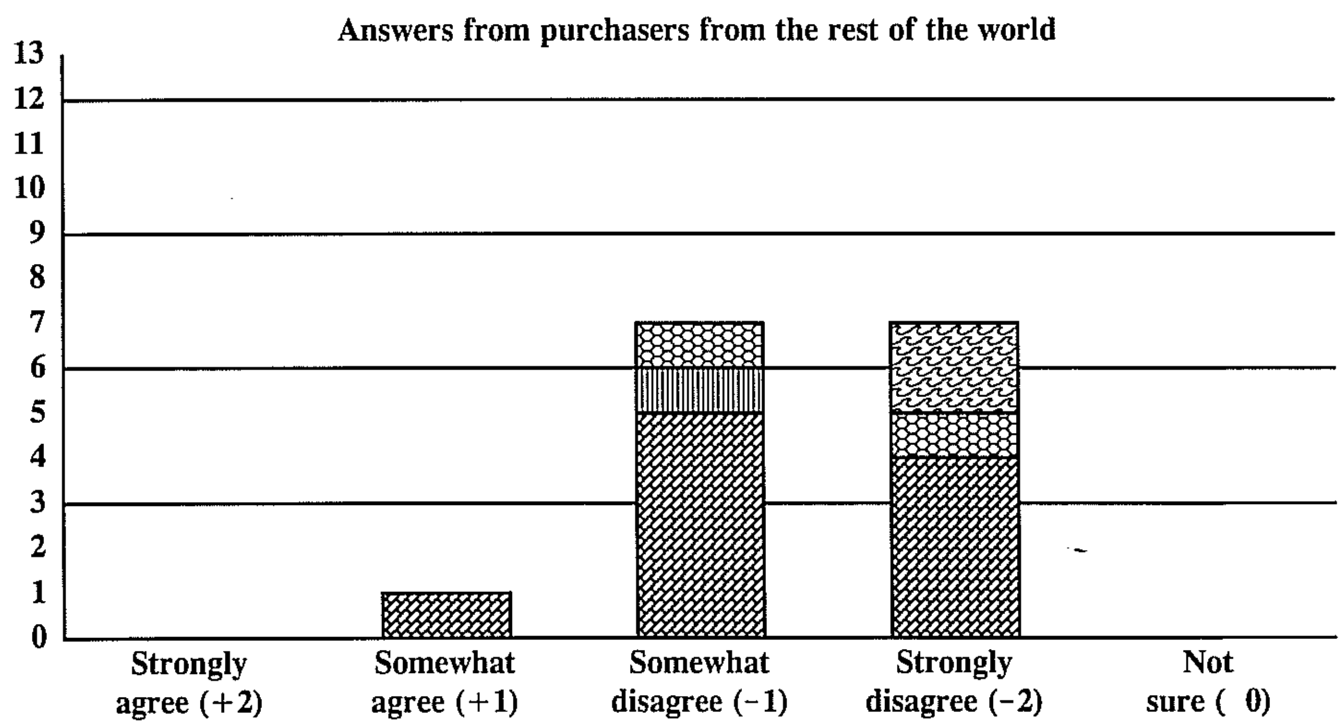




Handpump purchasers' survey: statement 27

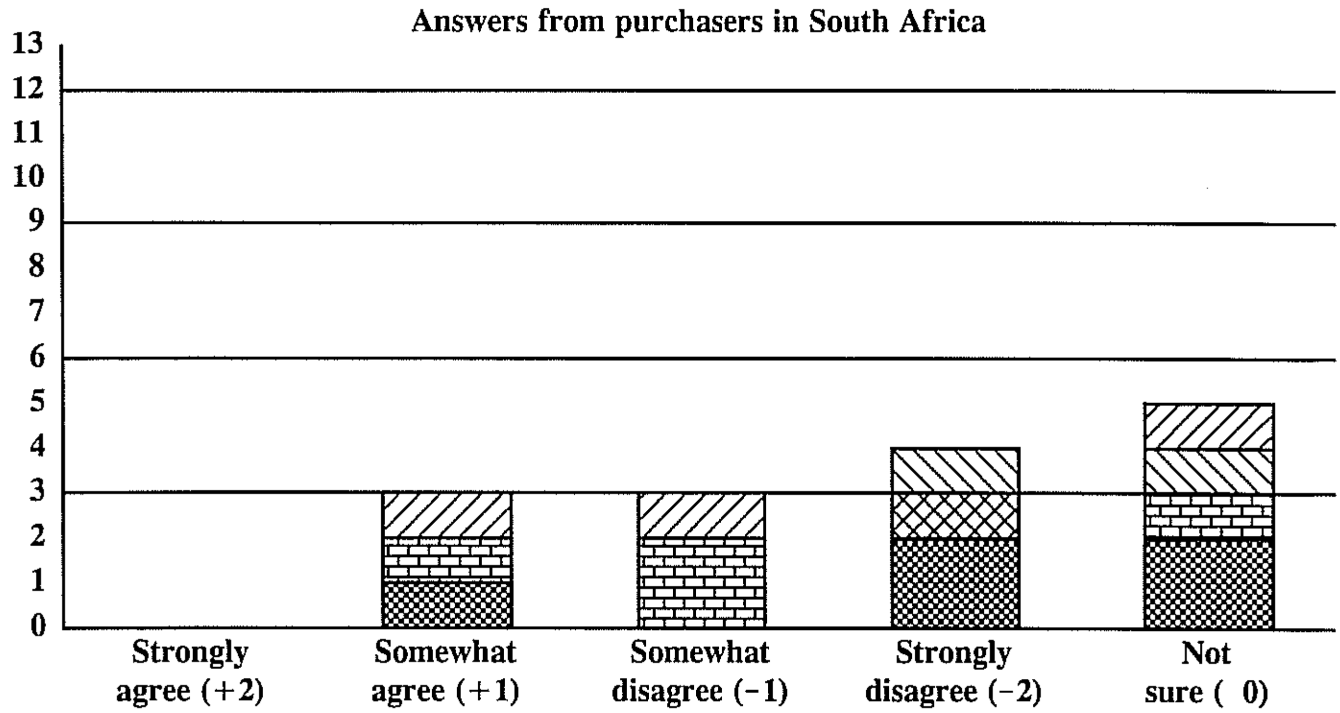
Pump abrasion can be ignored when purchasing a handpump.

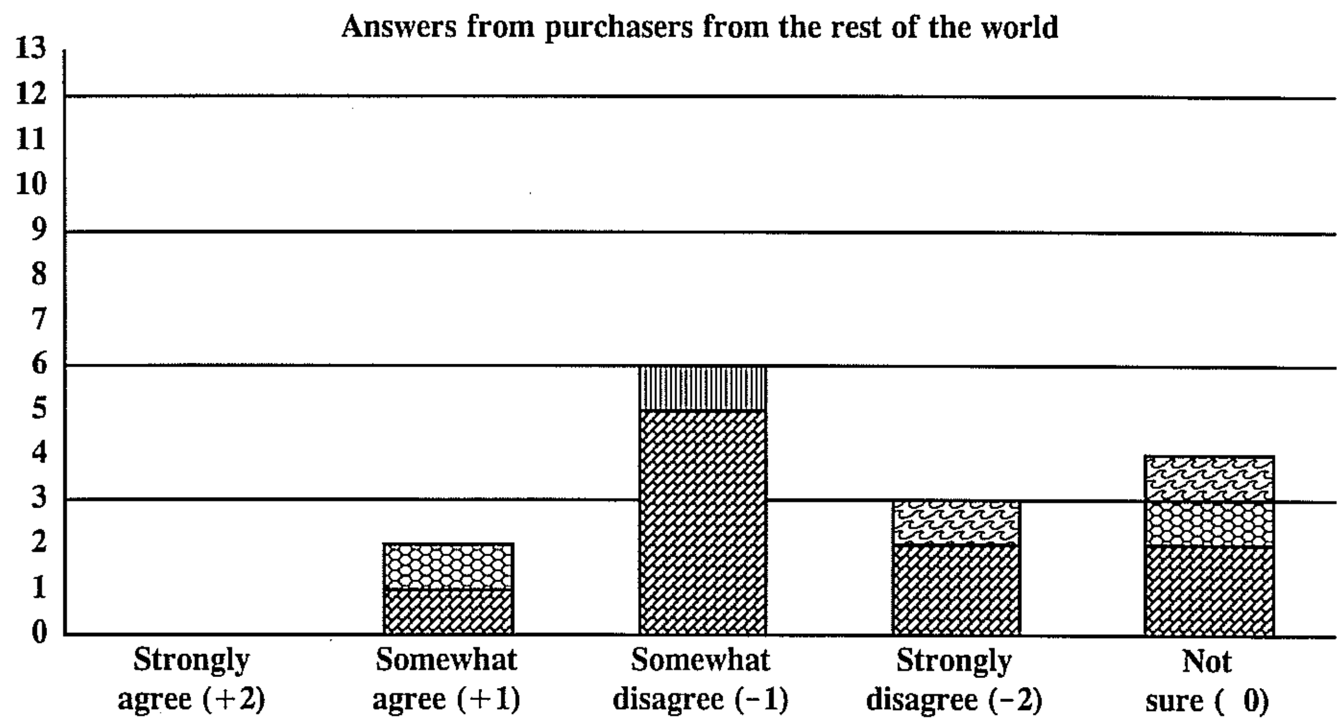




Handpump purchasers' survey: statement 28

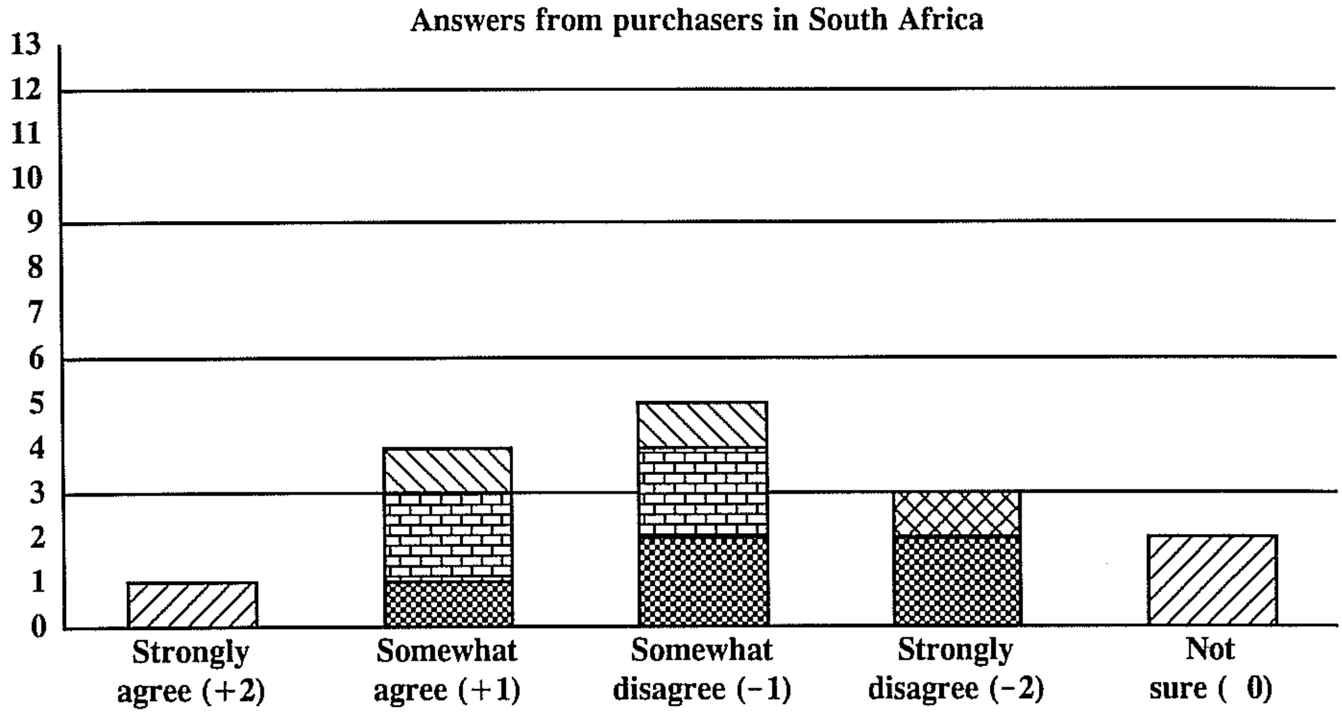
Progressive cavity pumps are superior to piston pumps for all handpump duties except maybe low heads up to 10 m.

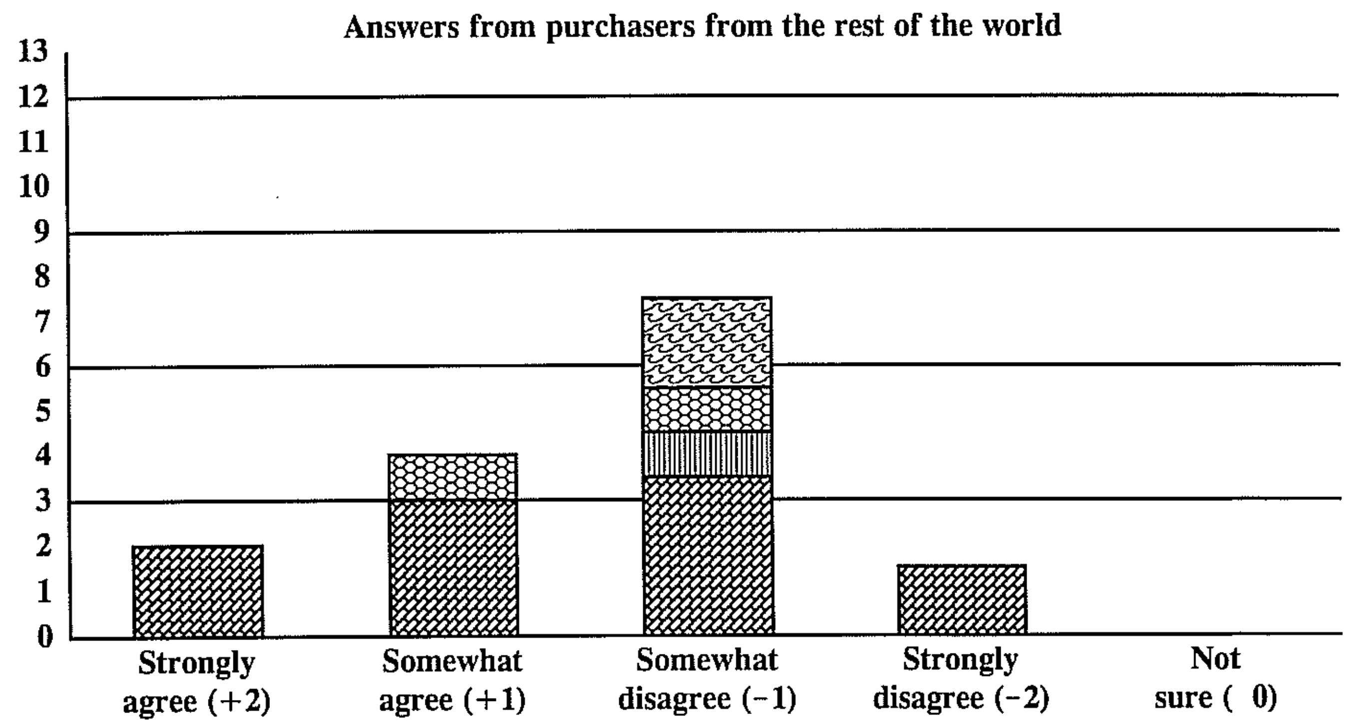




Handpump purchasers' survey: statement 29

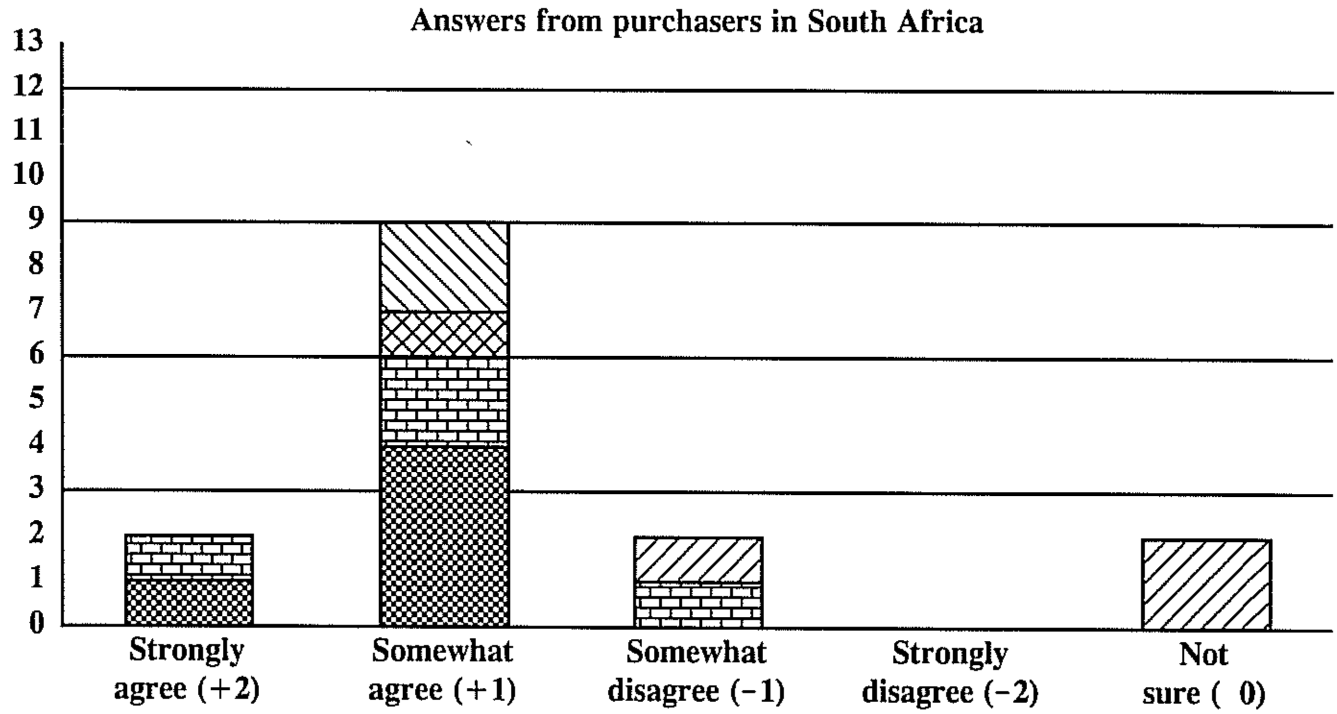
People generally want pumps that deliver the most water even if this makes them a bit more difficult to operate.

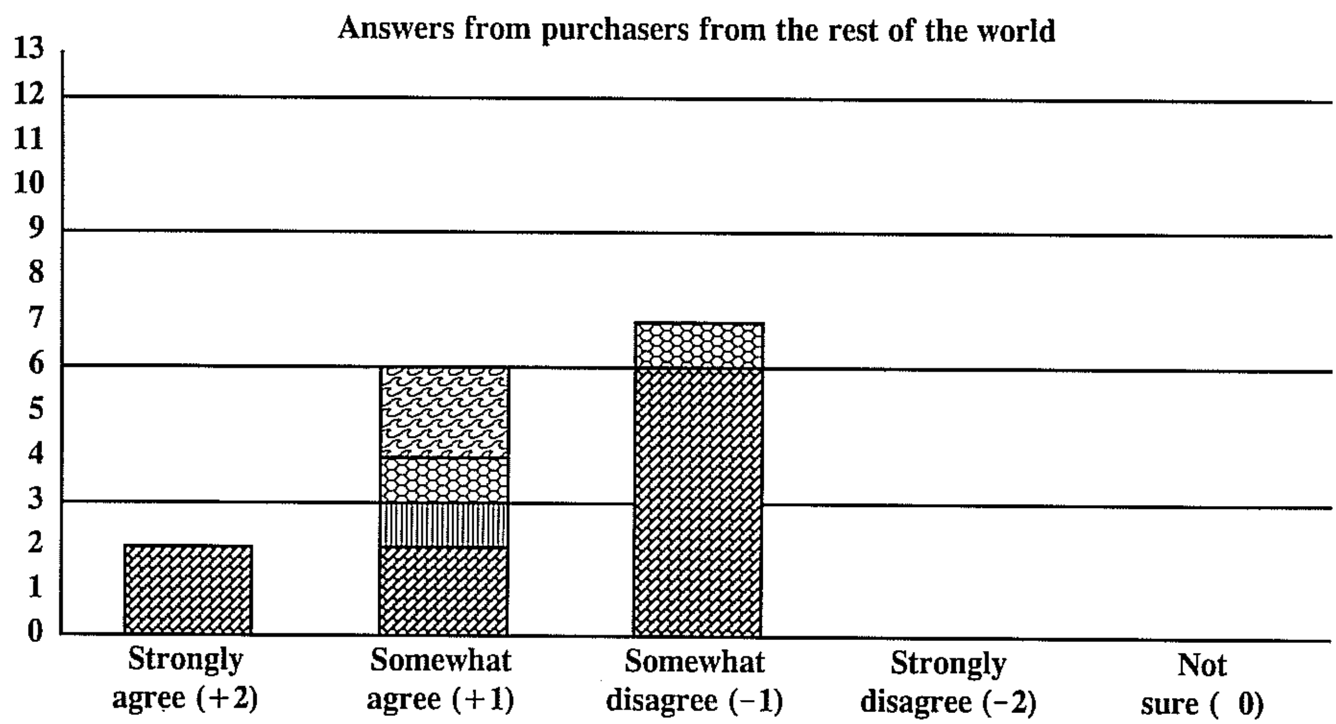




Handpump purchasers' survey: statement 30

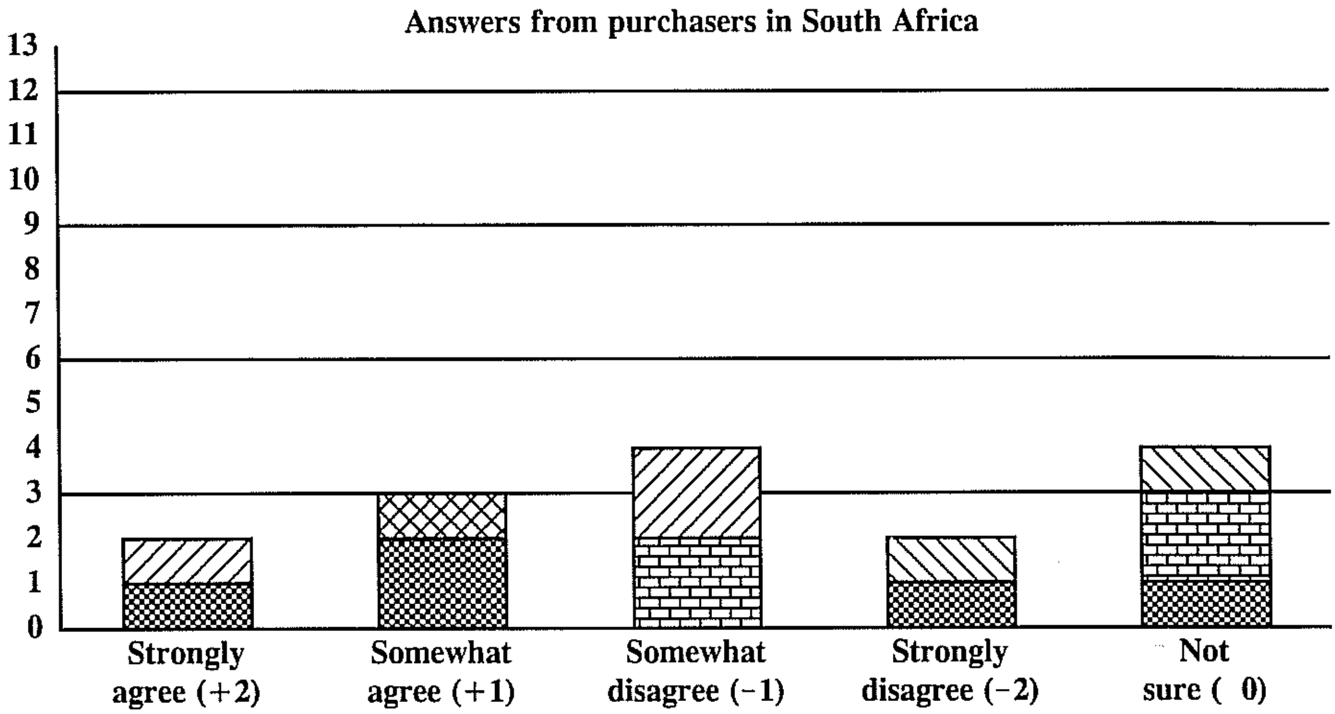
Ease of operation is more important than the rate at which water is delivered.

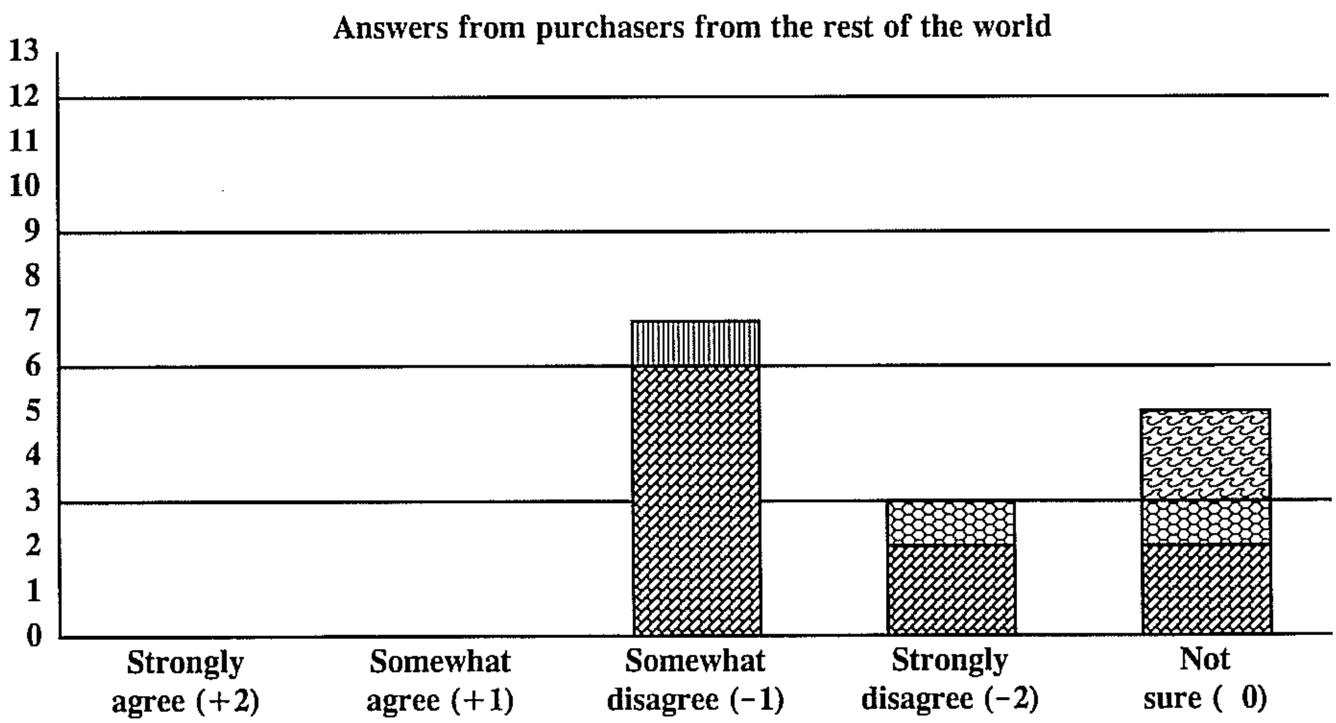




Handpump purchasers' survey: statement 31

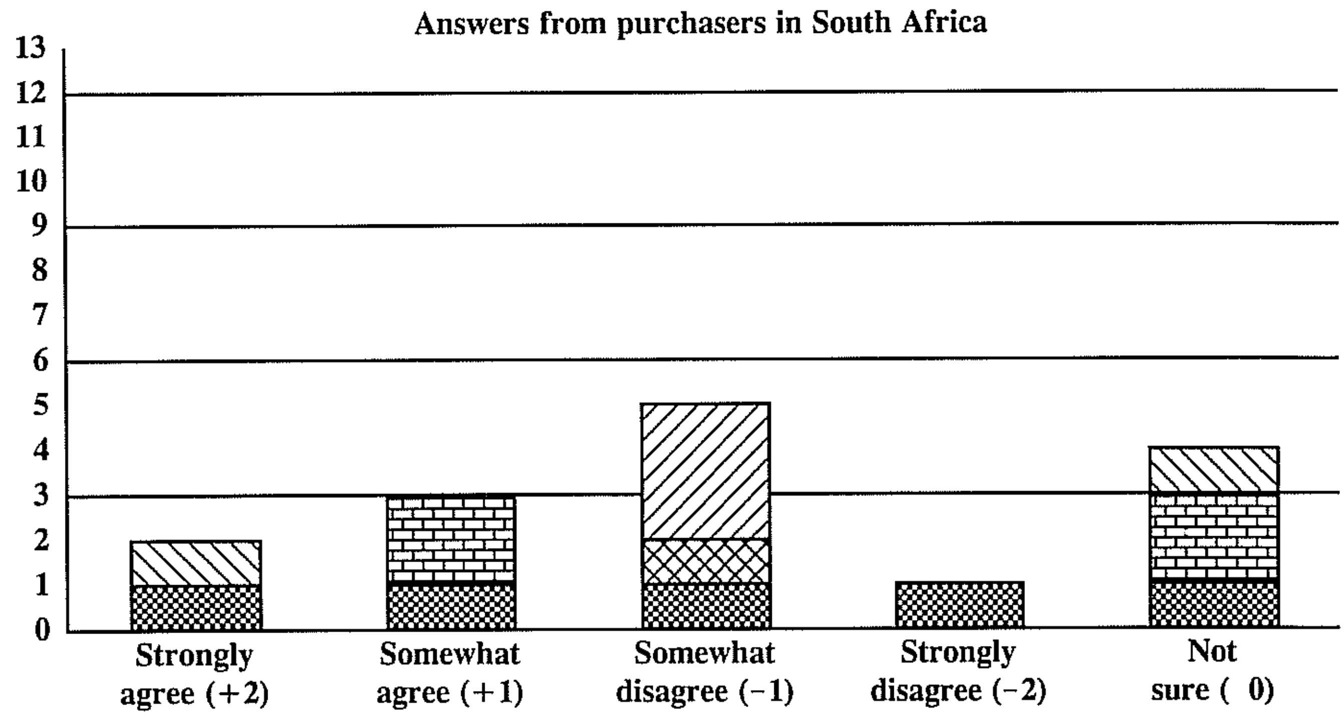
People prefer wheel-operated pumps to lever-operated pumps.

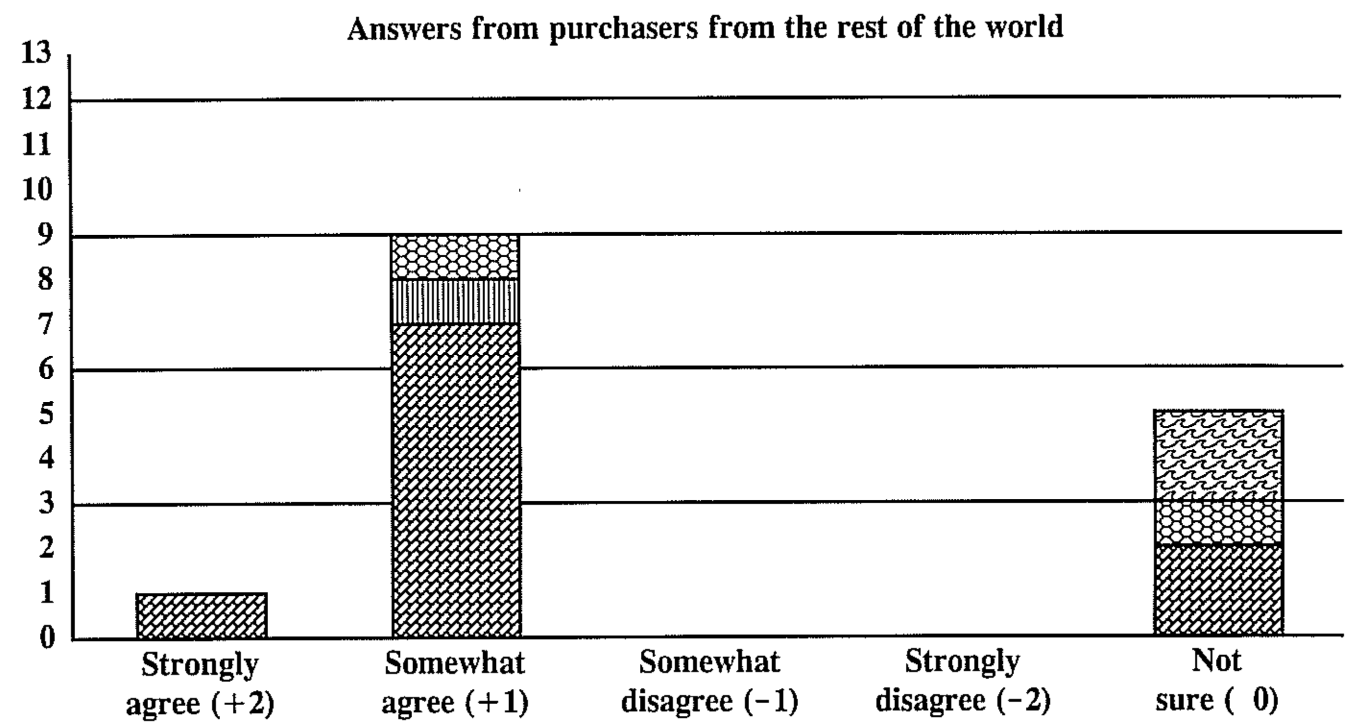




Handpump purchasers' survey: statement 32

People prefer lever-operated pumps to wheel-operated pumps.





ANNEXURE E

HANDPUMP USERS' QUESTIONNAIRE

AND

NOTES FOR THE INTERVIEWER

Dear Interviewer

OBJECTIVES OF THE HANDPUMP PROJECT AND HOW IT IS BEING IMPLEMENTED

Thank you for showing an interest in this project which aims to improve the effectiveness of handpump installations in meeting community needs in a cost-effective manner. Implementation of the project has been divided into two phases:

- phase 1 aims to evaluate current practices to highlight community preferences and problem areas, and
- phase 2 aims to formulate a strategy for overcoming the key problems highlighted during phase 1.

For phase 1 we are:

- visiting pump manufacturers,
- comparing and contrasting what is happening in South Africa with what is happening in other countries,
- asking handpump buyers how and why they buy the pumps they do, and
- issuing these questionnaires, which aim to find out from the users themselves what they think: a crucial requirement of phase 1.

Therefore, anything you the Interviewer can do to help the users communicate with us will be greatly appreciated.

HANDPUMP USERS' QUESTIONNAIRE

We anticipate this questionnaire to be administered by someone outside the community although it is the handpump users' evaluation of their own situation which we need. However, any communities who get copies of this questionnaire and photocopies of the cards for answering question 2.1 are most welcome to ask a community leader to help them complete it.

The main aim of the questionnaire is to find out how community users view their handpump installations and what the critical problems are which prevent handpumps from being an effective means of delivering water to communities.

The questionnaire is divided into five sections. The first two cover:

1 Introductory questions related to the interviewer and the community

2 Basic preferences, problems and background information

whilst the last three sections:

3 How are the handpumps cared for?

4 Handpump breakdowns and repairs

5 Community structures and attitudes

cover more specific issues.

COMPLETING THE QUESTIONNAIRE: NOTES TO THE INTERVIEWER

General Note:

We need the handpump users' evaluation of their own situation. Please try and get a group of about 10 or so **handpump users** around you: young women and older women, and children. If there are any community leaders present, especially male ones who never actually collect water, ensure that it is the handpump users who dominate the interview. It is important that users dominate the interview and that even you yourself, the interviewer, don't allow your preferences and evaluation of the situation to influence what appears in the completed questionnaire. We, the team who formulated the questionnaire, have tried to keep our preferences out and to make the questionnaire as universal as practical. Despite all these comments, the presence of a **pump caretaker** could facilitate improving the quality of the information obtained for Sections 3 and 4. **Community leaders** may also be able to assist in obtaining improved information for Section 4. We are with you in spirit as you bridge the gap between us and the communities.

Section 1:

No special instructions needed.

Section 2:

2.1 Users' preferences: The two sets of cards with pictures of handpumps on them will assist you when asking the community to tell you which handpumps they prefer.

The 1st set (pink background), comprising 4 cards, depicts 4 different types of handpump found in the rural areas of South Africa. Three of these cards have a picture of two different, but similar, handpumps. The object of this set of pictures is to help the users to let you know what types of handpumps they **have** in the village, what types they **know** and to help them **state their preference between two similar alternatives.**

The 2nd set (green background), comprising 7 cards, repeats the information shown on the 1st set but with only one picture per card. These cards allow you to pick out the communities' preferences from the previous exercise and so help the community **to rank their overall preferences from the different broad types** of handpump available.

ADDITIONAL NOTE: The cards with the pictures of the handpump installations have been drawn with the primary aim of helping community members to recognise the different types of handpump found in their area. For this reason we have shown each pump mounted on a small square plinth as most commonly seen throughout the rural areas of South Africa. These square plinths are not ideal from the point of view of hygiene. Our production of these cards is therefore not to be interpreted as meaning that the CSIR approves of the construction of such plinths.

Referring to the 1st set of pictures (pink background):

Card 1 depicts wheel-operated piston pumps. The theory is that the smooth motion achieved by using a wheel makes these pumps superior to lever-operated pumps; a big wheel being even smoother than a small wheel. Some people say women generally find all wheels awkward. Whilst the big wheels, once you get them going, are definitely smoother to operate some people say that getting these wheels started is so difficult that children end up rocking them instead of turning them right round. The smooth motion may also make them more reliable. Find out what the users think.

Card 2 depicts the common lever-operated piston pump. The top picture depicts a conventional lever. The bottom picture has a "**T**" at the end of the handle so that the operator can stand behind it and press down evenly with both hands. Do those who are familiar with this "**T**" find it useful or do they find that it is something that gets in the way?

Card 3 depicts another type of pump. Unlike conventional single-acting reciprocating piston pumps which only deliver water on the downward stroke, this pump has a helical rotor which turns in a fixed stator and continuously delivers water as the actuator is turned. The top picture shows a gearbox usually designed so that for every complete turn of the handwheel the pump turns more than once. This increases the amount of water pumped but the user has to push harder on the handle to work the pump. The second picture shows a simple direct drive with even fewer parts that can malfunction. What do the users think? Is the gearbox an advantage or do they prefer the simplicity of the direct drive?

Card 4 depicts a direct action piston pump. This type of pump is only useful for pumping water from a maximum depth of about 12 metres. Up to this depth, many people say that it is the best pump to use because overall it delivers the most water. What do the people that use them think? Do they prefer one of the other pumps even for low-head duties or not?

As already stated, the object of the pictures is to discover which handpumps users **have** in the village, which handpumps users know, their preferences for each of the four broad types and also their preference for specific types within the four broader types. We believe this is best done in the following manner:

* Round 1: Take out the 1st (pink background) set of 4 pictures. Shuffle the "pack" so that the order in which they are presented to the community is random. (The sets and numbers within each set have been chosen at random in drawing up this questionnaire also.) Show the handpump users being interviewed each card in turn and ask **how many of each type of handpump** they have in the village.
* Round 2: Show the handpump users each card in turn a second time round and get a general reaction as to whether or not they **recognise each of the handpumps** shown and **what they think of them.**
* Round 3: If not already learnt in round 2, for each card with more than one picture, ascertain **which of the two pictures on the one card they prefer.** In this round it is also important to ascertain whether or not each type is known. Only record preferences and "don't know it".
* Round 4: From the 2nd set of cards (green background) pick out the cards corresponding to preferences selected in rounds 2 and 3. You will therefore be picking out a maximum of 4 cards and a maximum of only one picture from each 1st-set-card with a picture of two pumps. (If the community are familiar with the direct action piston pump include the picture of this unit also. If users have a mixed reaction to a picture in the 1st set because, for example, of a strong dislike for one of the two choices on the card, it is still important to include the preferred pump from that card when deciding the overall ranking preferences.) Shuffle the chosen cards and ask the community **to rank their overall preferences.**

Typical sets of answers:

Set Actuator/Pump Type	Which pumps do you have in **this** village. State number of each		2nd round. General reaction	3rd round. Preference within set	4th round. Preference overall ranking
1 Wheel Piston	1.1 Big		*know*	*prefer*	*3*
	1.2 Little		*uncertain*		
2 Lever Piston	2.1 Std		*know*	*unsure*	*1*
	2.2 **T**		*like*	*don't know it*	
3 Rotary Screw	3.1 Box		*know*	*prefer*	*2*
	3.2 Dir		*uncertain*		
4 Direct Piston	4.0 Dir		*don't know it*	N/A	-

Set Actuator/Pump Type	Which pumps do you have in this village. State number of each		2nd round. General reaction	3rd round. Preference within set	4th round. Preference overall ranking
1 Wheel Piston	1.1 Big		*don't know them*	-	-
	1.2 Little			-	
2 Lever Piston	2.1 Std		*know uncertain*		*2*
	2.2 **T**			*prefer*	
3 Rotary Screw	3.1 Box		*know like*		*3*
	3.2 Dir			*prefer*	
4 Direct Piston	4.0 Dir		*know, like*	N/A	*1*

2.2 Users' problems: In this section we first want the users to describe their problems, **without any prompting from the interviewer,** in an unstructured way. A number of likely responses are recorded on the questionnaire. As users describe their problems **write down** 1, 2, 3 etc **in the "Unsolicited" column** as the comments are made. The bottom of the box allows you to add additional response as they are made. You can also add other general comments made by users in the top of the box.

When **and only when** the users have exhausted their comments, the interviewer should ask about issues listed but not mentioned by the users. If the response to any of the issues raised suggests that there is a real problem despite the fact that it was not communicated spontaneously, place an "x" in the **"Canvassed"** column.

2.3 Which is the bigger problem: In this section we revisit 4 common problems related to many handpump installations in South Africa to check with each community which ones it finds the bigger problem. **It is important that each of the two pairs of questions are asked first**, before finally asking the community to choose between the pair of problems which will then sit in the middle two boxes to the right of four larger boxes.

The rest of the questionnaire is structured and generally comprises straight forward questions. We feel that no special instructions are needed for these. However should you experience any problems in the field please do contact us for clarification at:

CSIR Environmentek
Water Resources Management Programme
PO Box 395
PRETORIA
0001 South Africa

Tel: +27 12 841-2341
Fax: +27 12 841-3954

or at

TSE Water Services
57 Twelfth Street
ORANGE GROVE
2192 South Africa

Tel/Fax: +27 11 640-6543

It will be appreciated if you return as many completed questionnaires as possible to us within six weeks, so that we can process them and determine if the sample size is satisfactory.

Again thank you for assisting us to complete this crucial aspect of phase 1.

Derek Hazelton
Project Leader

Monique Meiring
Lead Sociologist

**THE DEVELOPMENT OF
EFFECTIVE COMMUNITY WATER SUPPLY SYSTEMS
USING DEEP AND SHALLOW HANDPUMPS**

**A WATER RESEARCH COMMISSION-FUNDED PROJECT
BEING IMPLEMENTED BY
THE WATER RESOURCES MANAGEMENT PROGRAMME
ENVIRONMENTEK CSIR**

HANDPUMP USERS' QUESTIONNAIRE

This questionnaire forms part of a Water Research Commission Project being undertaken by the CSIR. Your time in answering this questionnaire is greatly valued and your contribution to the project is appreciated.

Section 1: Introductory questions related to the interviewer and the community

1.1 Today's date: (yy/mm/dd)

/	/	/

1.2 Name of interviewer:

1.3 Contact address for interviewer:

	Code	

1.4 Contact telephone number:

Code		

1.5 Name of community and province in which it is situated:

Name		Prov	

1.6 Location of community:

Name of nearest town		Distance from nearest town	
Latitude		Longitude	
Farm name and number		Magisterial district	
Directions to community			

1.7 Name of contact person in community:

1.8 How many families/households and people live in the community?

No. of families/households		No. of people	

1.9 Description of person(s) being interviewed:

No. pensioners		No. men		No. women		No. children	
No. pump users				No. of pump caretakers			

Section 2: Basic preferences, problems and background information

Refer interviewers' notes for our recommended method of conducting this part of the interview

2.1 Peoples' overall preferences for 4 broad types of handpump and their preferences for specific types within these broader types

Set Actuator/Pump Type	Which pumps do you have in this village. State number of each		2nd round. General reaction	3rd round. Preference within set	4th round. Preference overall ranking
1 Wheel Piston	1.1 Big				
	1.2 Little				
2 Lever Piston	2.1 Std				
	2.2 T				
3 Rotary Screw	3.1 Box				
	3.2 Dir				
4 Direct Piston	4.1 Dir			N/A	

2.2 What are the things about handpump installations which communities dislike most or present the greatest problems?

General comments made:		
Important things Responses	Unsolicited	Canvassed
We weren't consulted before the pumps were installed		
The pumps are difficult to operate		
The pumps don't pump enough water		
Sometimes there are long queues at the pump		
The pumps are too far away from where we live		
Water quality: it tastes bad		
Water quality: it's unhealthy, it makes us sick		
Water quality: the colour of the water is bad		
The pumps are always breaking down; they are unreliable		
When they break, the pumps don't get fixed for a long time		
Other		
Other		
Other		

2.3 Let's discuss 4 common problems a bit more: which is the bigger problem?

We spend too much time collecting our water because the pumps are too far away from where we live	**1A**		
Handpumps are very unreliable; they are broken down much of the time	**1B**		
Our handpumps are very difficult to operate: (pumps which pump less water but easier to operate would be better)	**2A**		
Our handpumps deliver the water very slowly: (pumps which pump more water even if it means working the pump harder would be better)	**2B**		

2.4 How many handpumps are there in this community?

2.5 Who actually uses the handpumps in the community?

2.6 Who owns the handpumps? (State number of each)

Private		Community	
Government		Another organisation	
Please specify if another:			

2.7 What is the water from the pumps used for?

Domestic water		Water for cattle	
Water for community gardens		Other	
Please specify if other:			

2.8 What is the best thing you have to say about the best handpump in the community?

2.9 What is the thing that causes you the most trouble with the worst handpump?

2.10 How many good and how many bad handpumps are there in the village?

Number good		Number bad	

2.11 How many handpumps are now working and how many are now broken?

Number working		Number broken	

2.12 Do your community depend only on handpumps for their water?

Yes		No	

2.13 Where else do you get your water from?

2.14 Are the handpumps useful when these other sources are not working?

Yes		No	

2.15 On average how far do people have to walk to use each handpump? How long does it take these people to walk home with the water they have collected?

m	minutes

2.16 At busy times, is there a queue of people waiting for water at the handpumps? How long do these people have to wait until they get water?

Yes		No		minutes

Section 3: Details of how the handpumps are cared for

3.1 Are there specific people in the community who care for the handpumps?

Yes		No	

3.2 How many handpump caretakers are there in the community?

Number	

3.3 Are you satisfied with the manner in which they care for the handpumps?

Yes		No	

3.4 How do they care for the handpumps?

3.5 Do the caretakers have any tools to do maintenance work?

Yes		No	

3.6 Where do the community get spare parts for the handpumps when they need them?

3.7 Does anybody from outside the community come to check how the pumps are working and to do maintenance before the pumps break down?

Yes		No	

Section 4: Handpump breakdowns and repairs

4.1 In the event that a handpump breaks down:

4.1.1 Is the breakdown reported to one particular person in the community?

Yes		No	

If yes, is that person the pump caretaker or another community leader? Describe the person:

4.1.2 Do the community ever repair handpumps themselves after a breakdown?

Yes		No	

If yes, describe what sort of repairs the community do themselves, and who does the repairs and how:

4.1.3 When a pump breaks down and the community cannot fix it themselves who is responsible for getting outside help?

4.1.4 Who usually does the repairs?

Government		Pump supplier		
Private repairman		If private repairman, where does he come from and what is the distance from there to the community?		
From where:			Distance	

4.1.5 How long does it take to get someone from outside the community to fix a handpump?

1 week		2 weeks		1 month	
2 months		3 months		More than 3 months	

4.1.5.1 If it takes a month or more why do you think it takes so long?

4.1.6 When a handpump breaks down, who usually pays for the repair work?

4.2 Why do you think handpumps usually break down?

There is no water in the borehole	
Some part of the pump in the borehole breaks	
Some part of the pump, shown in the attached picture, breaks	
Because of rough use or vandalism	
Other reasons given by the community	

SECTION 5: Community structures and attitudes

5.1 Is there a water/development committee in the community?

Yes		No	

5.2 Do the community have any ideas about how handpump installations can be made better and more reliable?

Yes		No		
If yes, give an indication of these ideas:				

5.3 Are the community interested in learning more about:

Handpumps that are less difficult to fix when they breakdown?	Yes		No	
Owning such a pump or pumps?	Yes		No	
How to care for handpumps?	Yes		No	
Organising cost recovery so that money is available to care for the pump?	Yes		No	

PLEASE NOTE THAT SHOWING INTEREST DOES NOT NECESSARILY MEAN WE WILL BE ABLE TO COME BACK AND HELP YOU INSTALL SUCH PUMPS. WE NEED TO FIND ABOUT 20 OR 30 COMMUNITIES CLOSE TOGETHER WHICH ARE INTERESTED IN SUCH A PROJECT BEFORE WE CAN CONSIDER TAKING IT FURTHER. EVEN THEN, WE WILL ONLY BE ABLE TO FACILITATE ONE SUCH PROJECT IN THE WHOLE OF SOUTH AFRICA. WE WILL, HOWEVER, APPROACH THE RESPONSIBLE AUTHORITIES IN YOUR AREA WITH YOUR REQUESTS.

Thank you for your time and your valuable contribution.

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and

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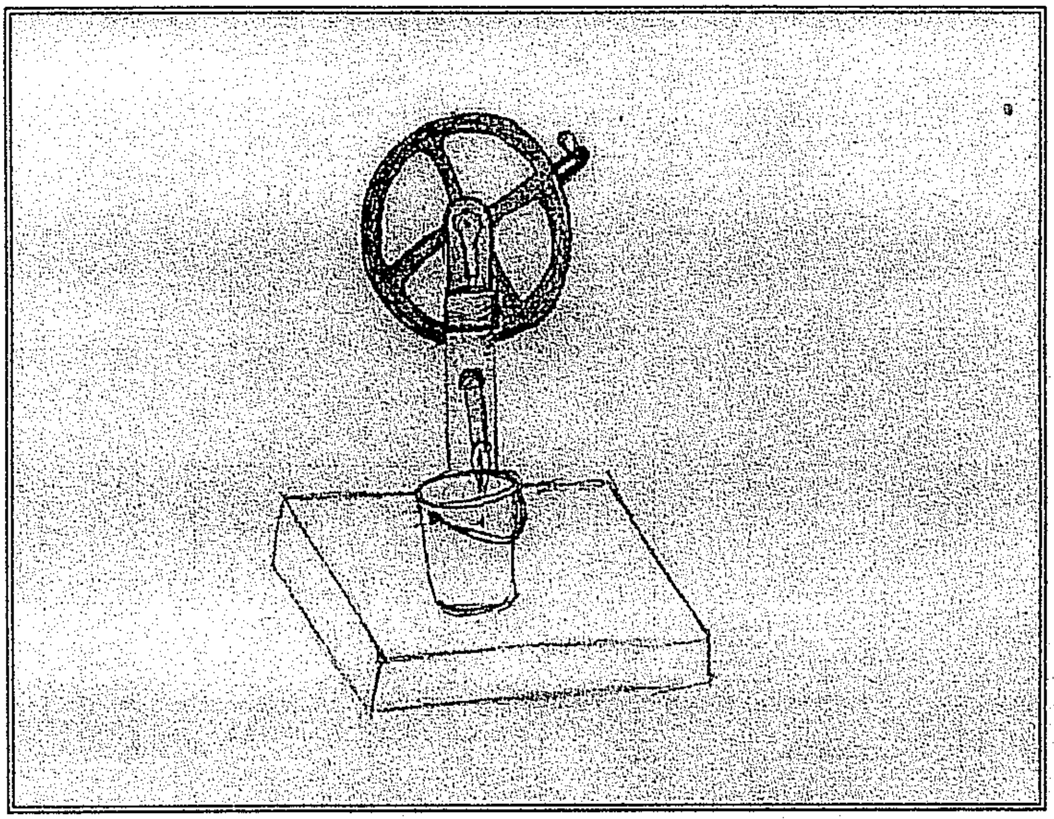
PINK BACKGROUND CARDS



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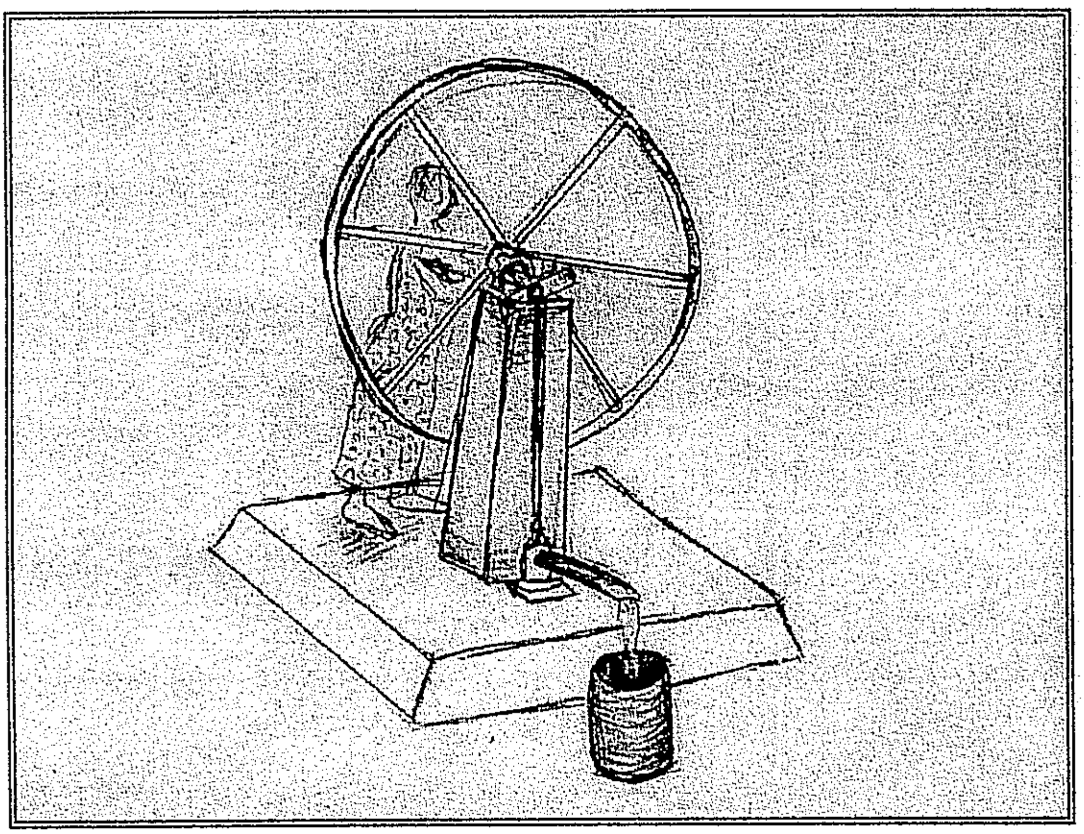

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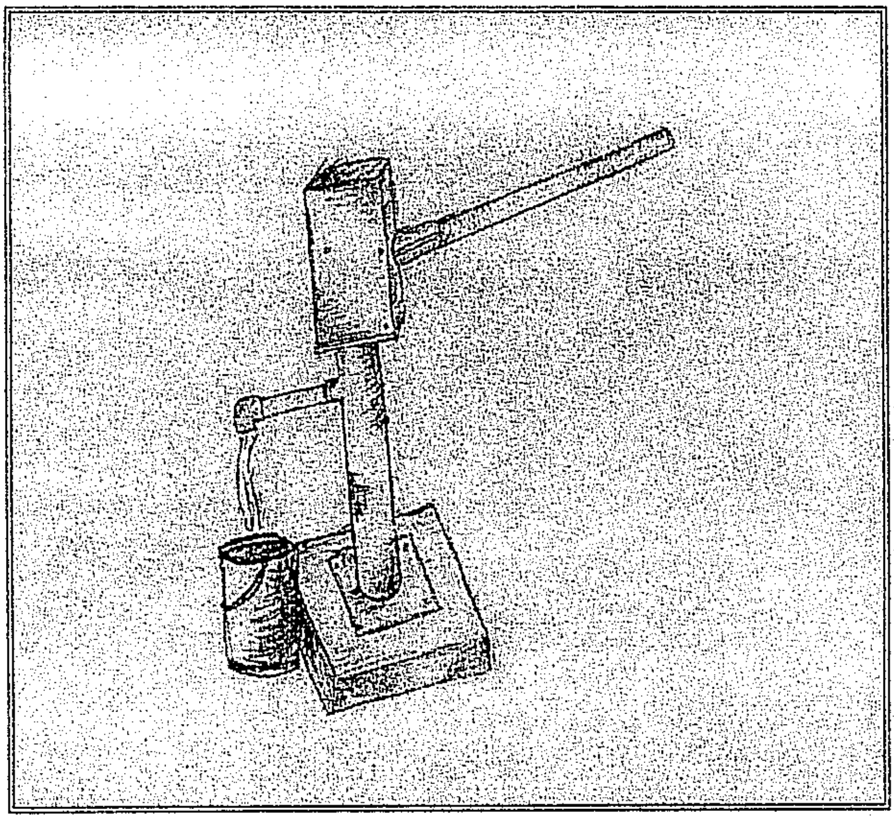

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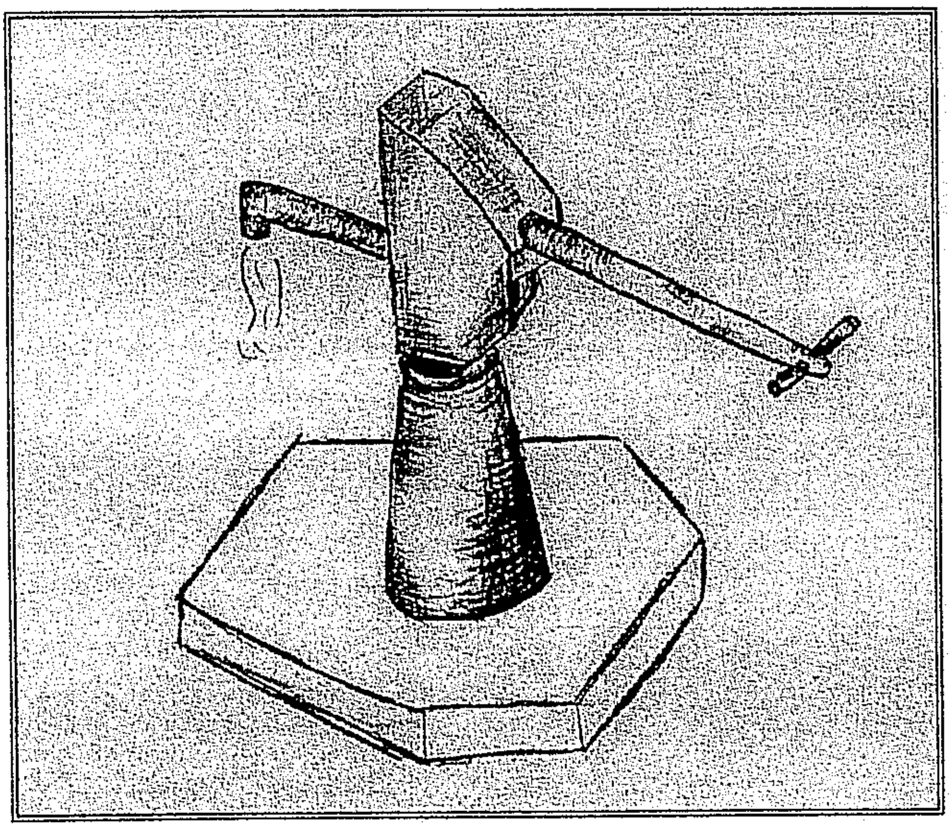

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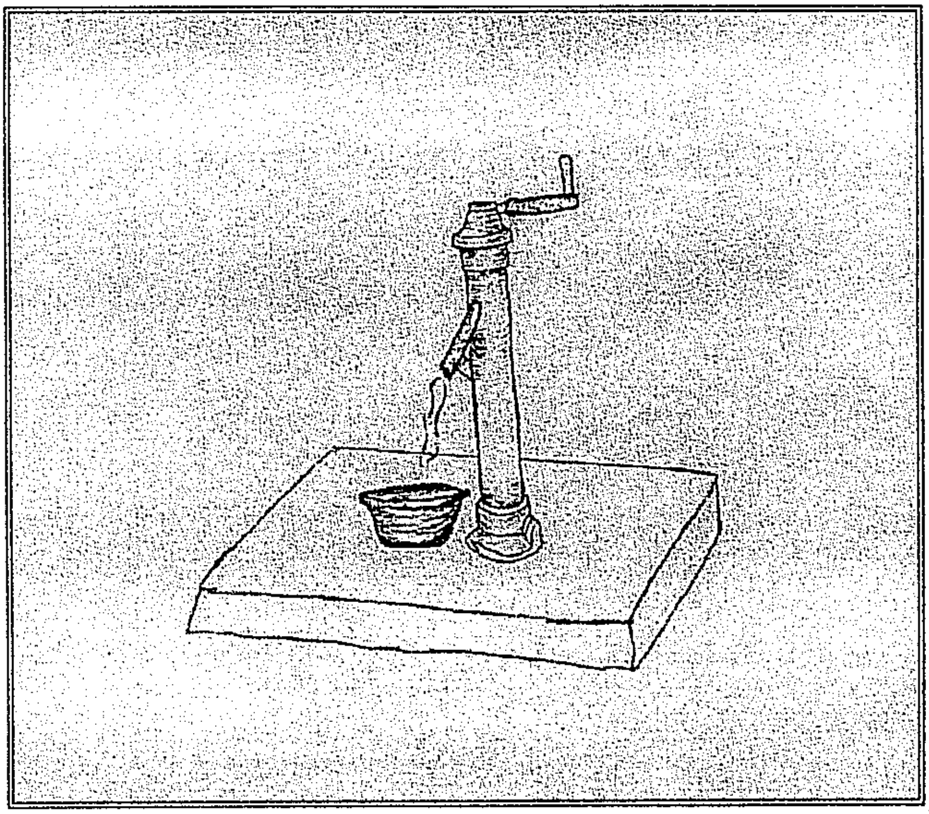

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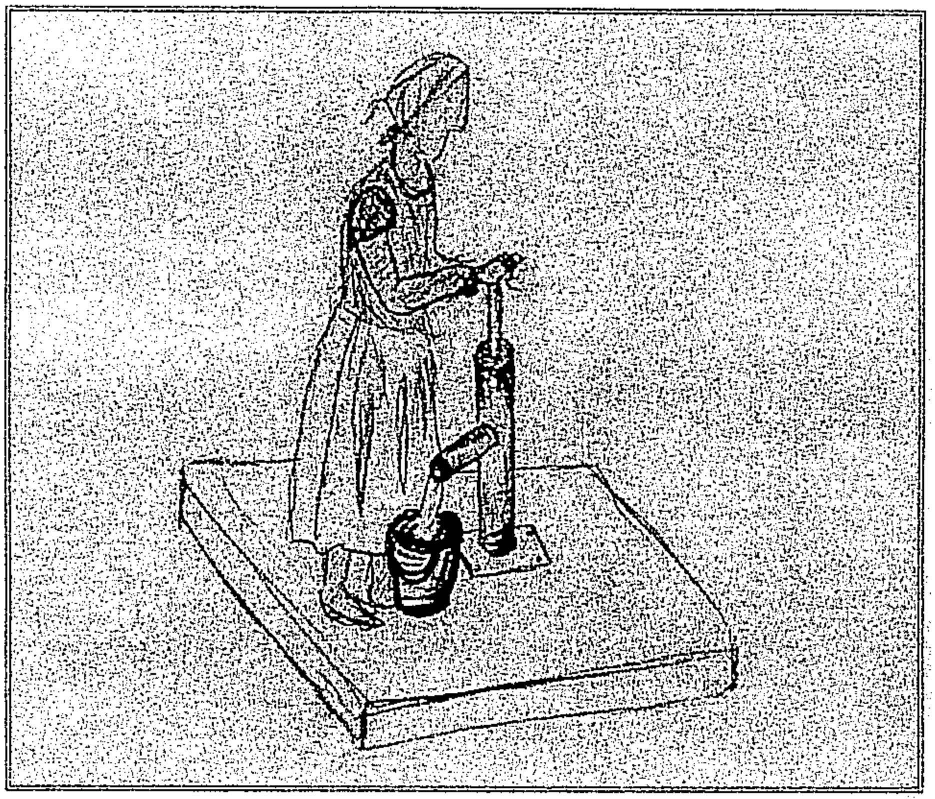

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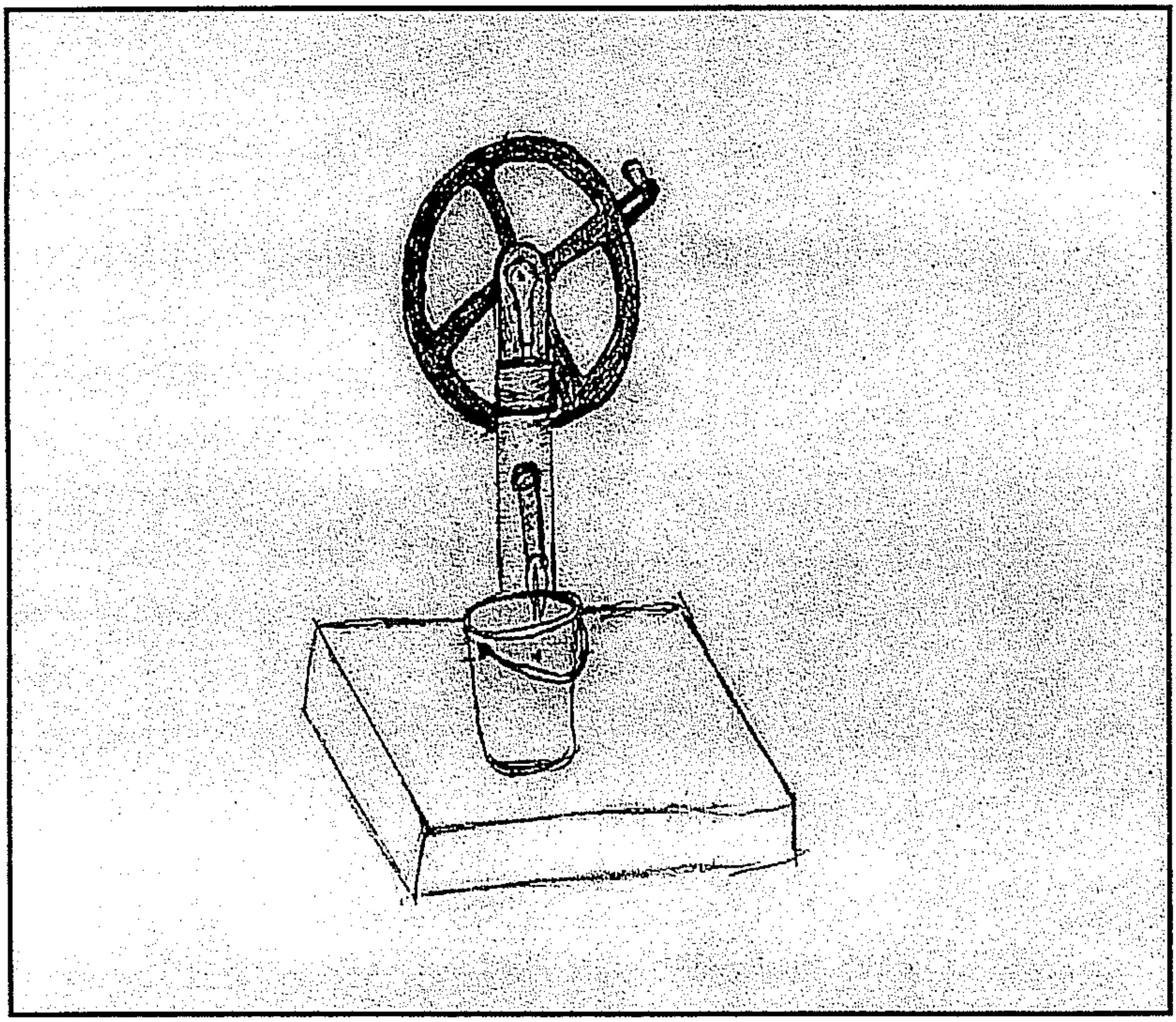

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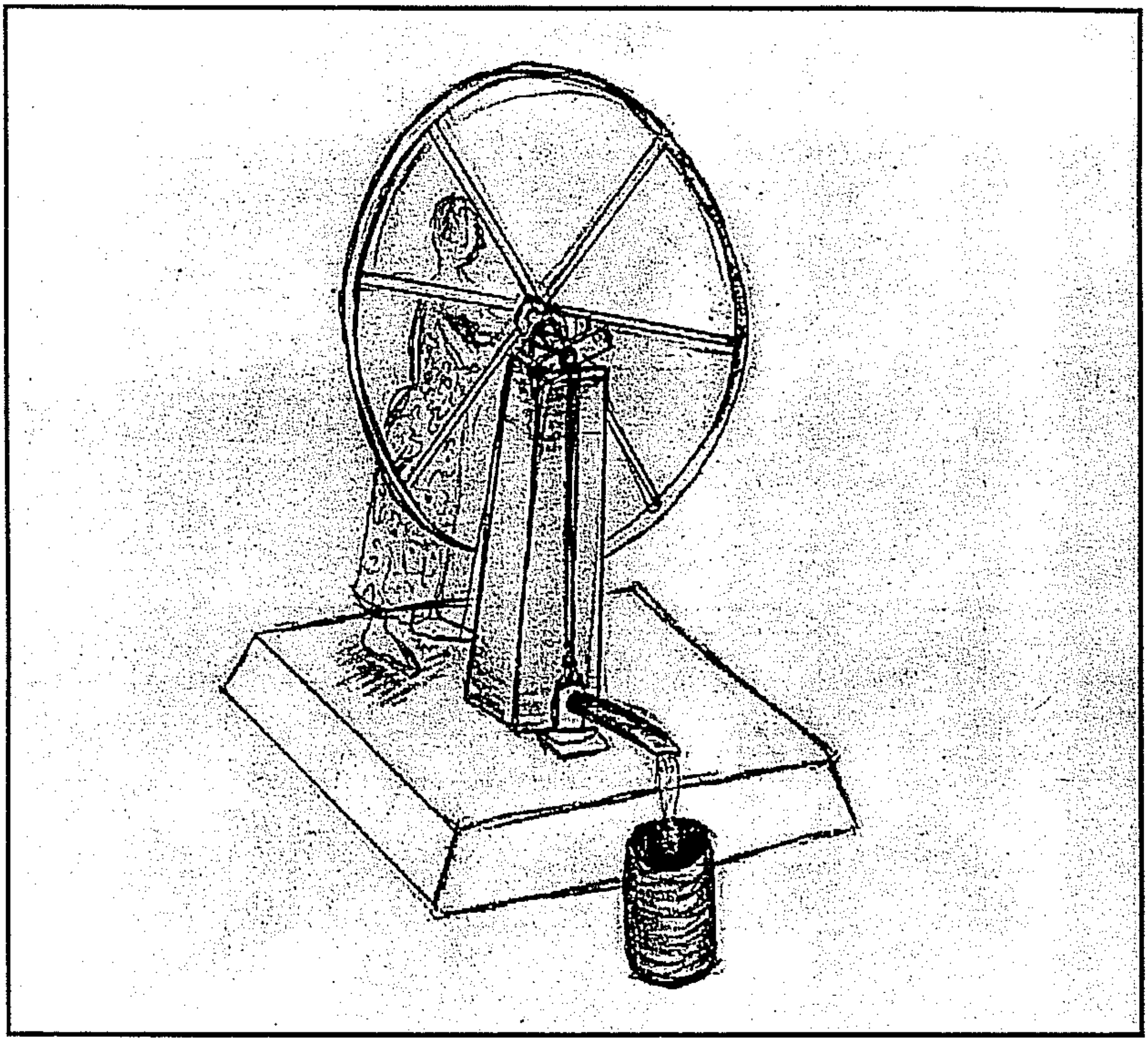

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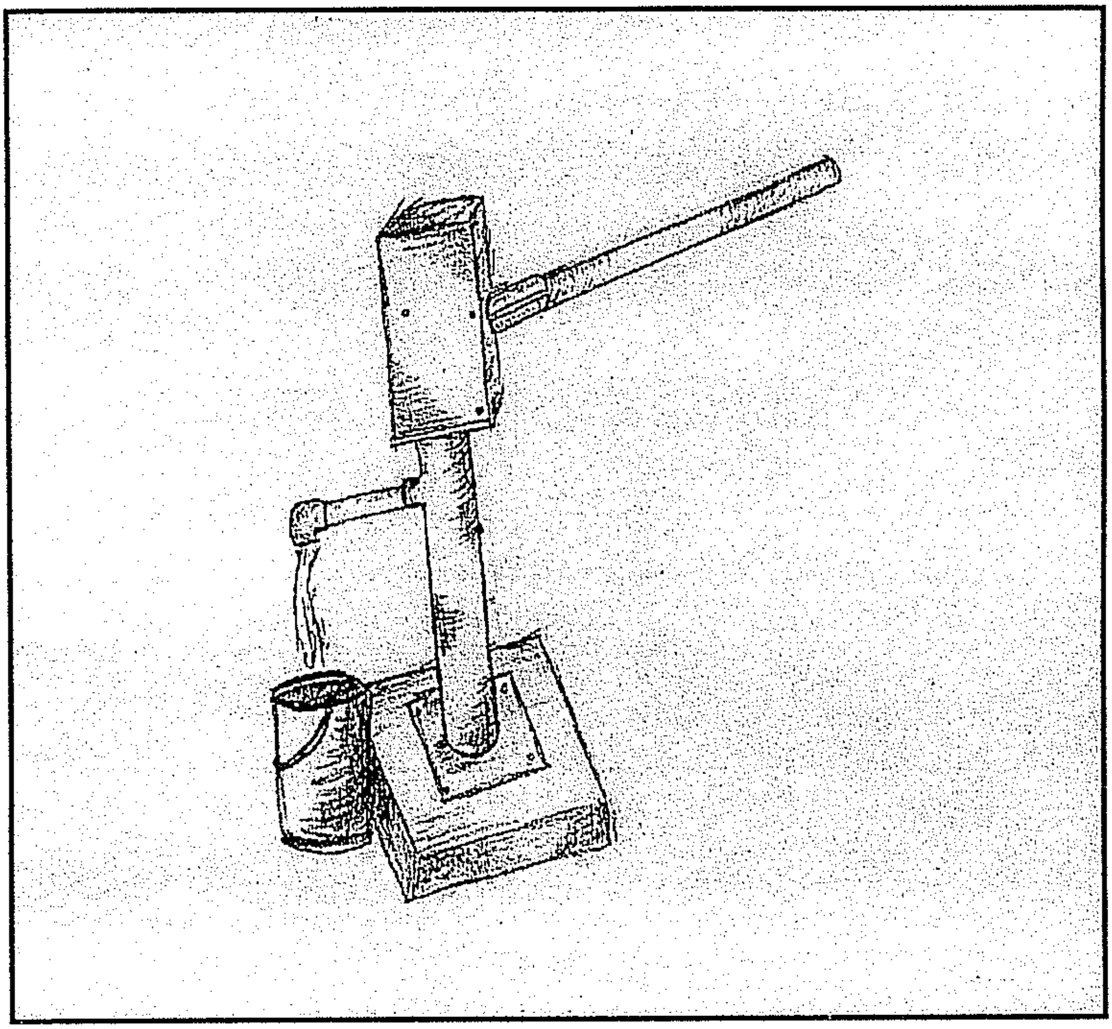

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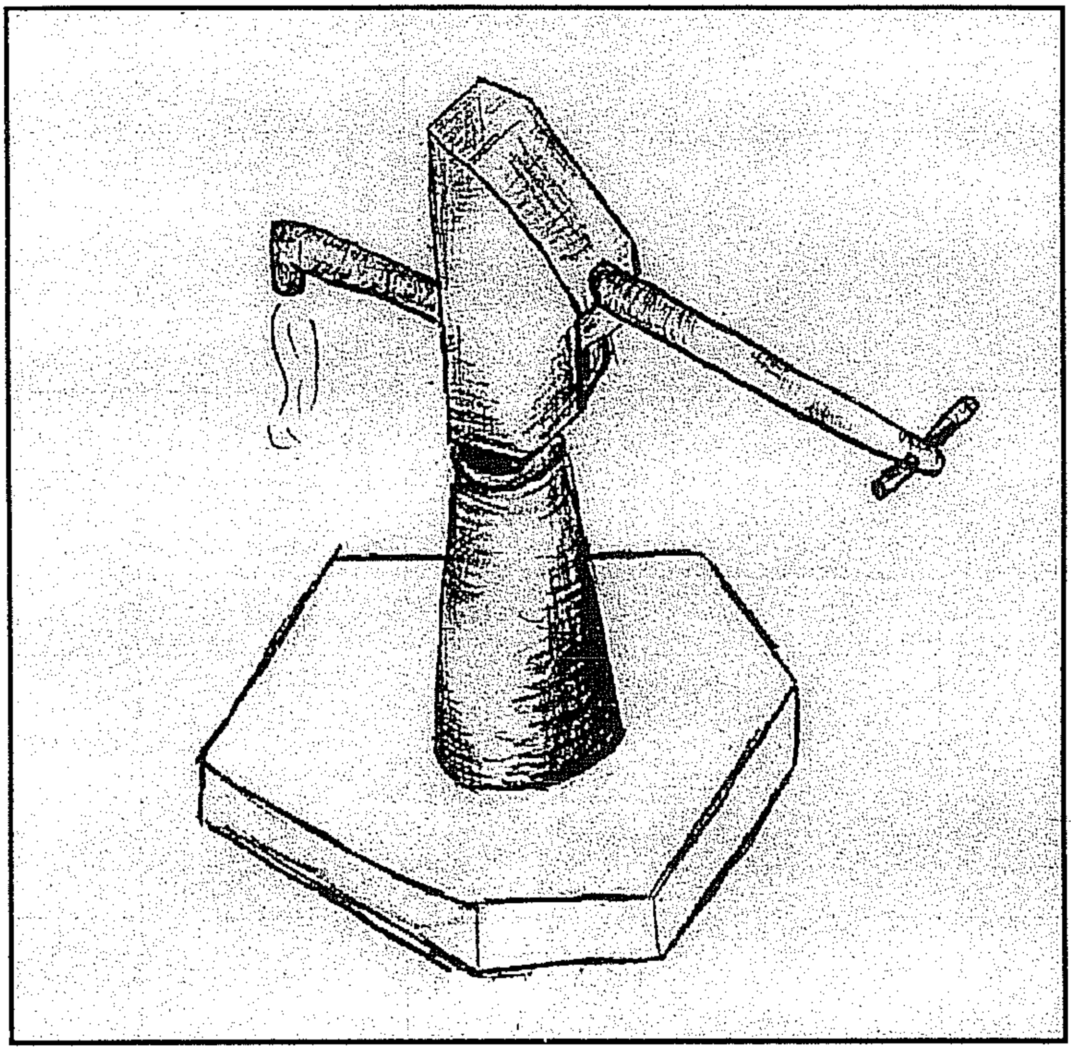

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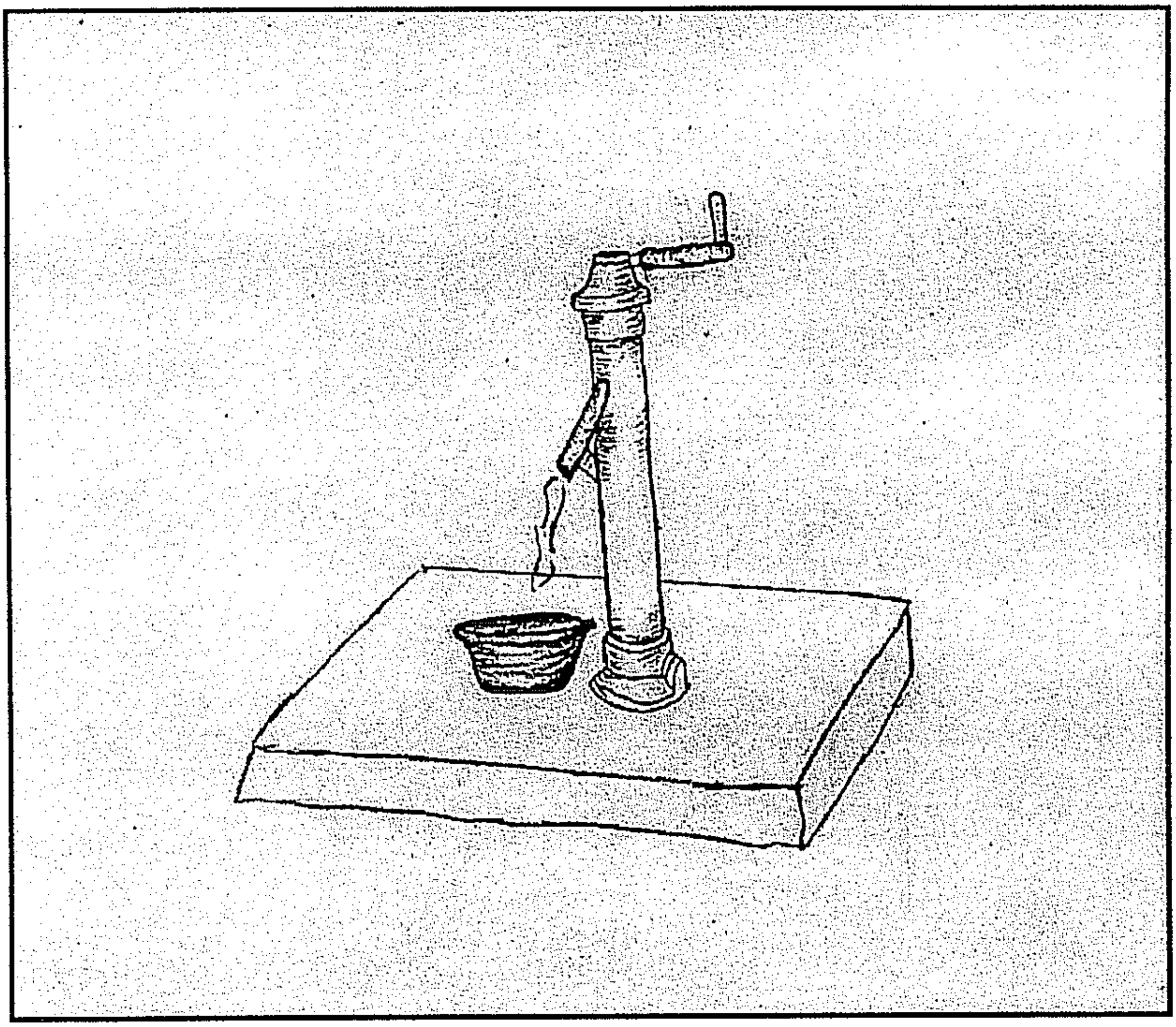

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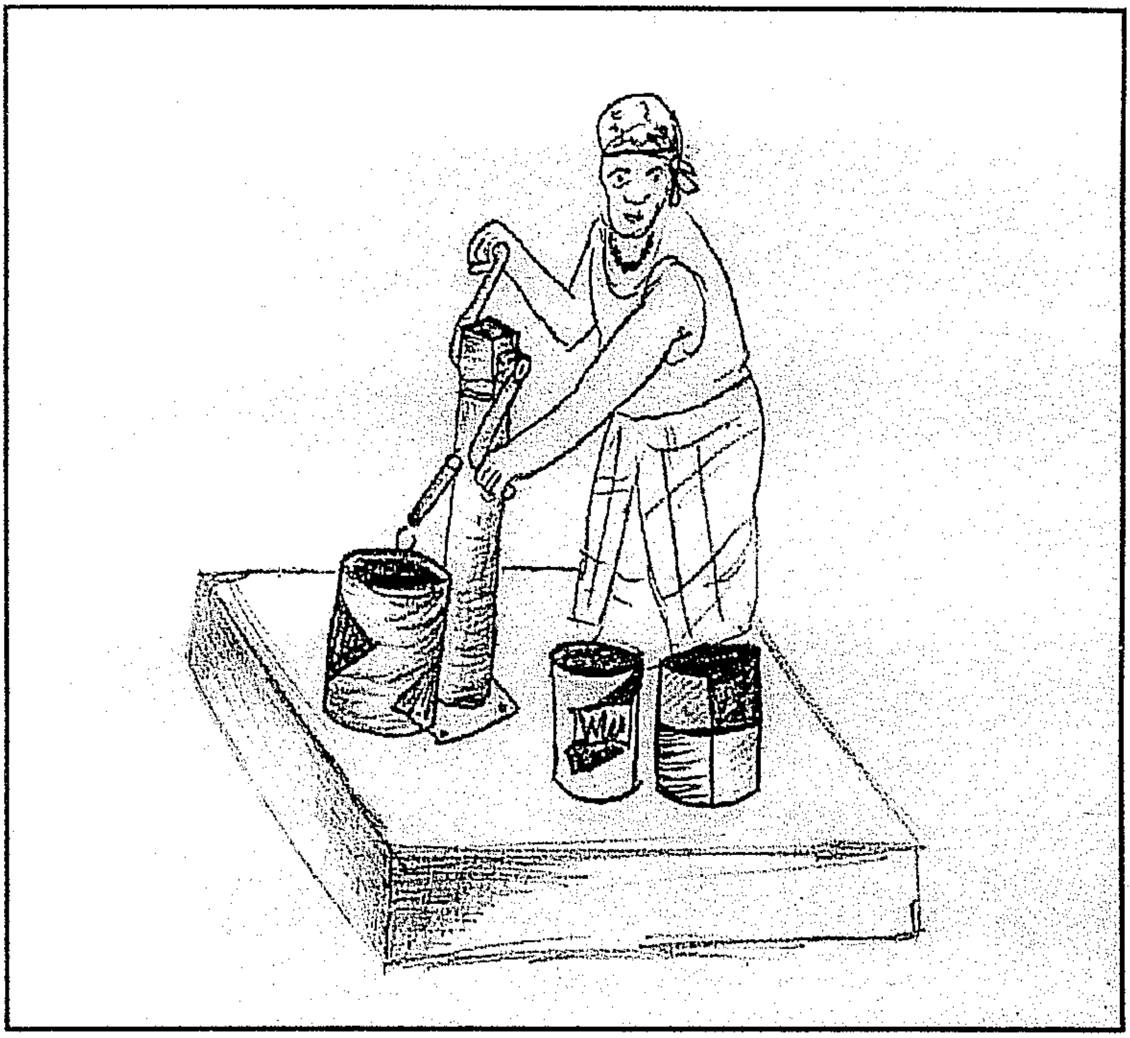

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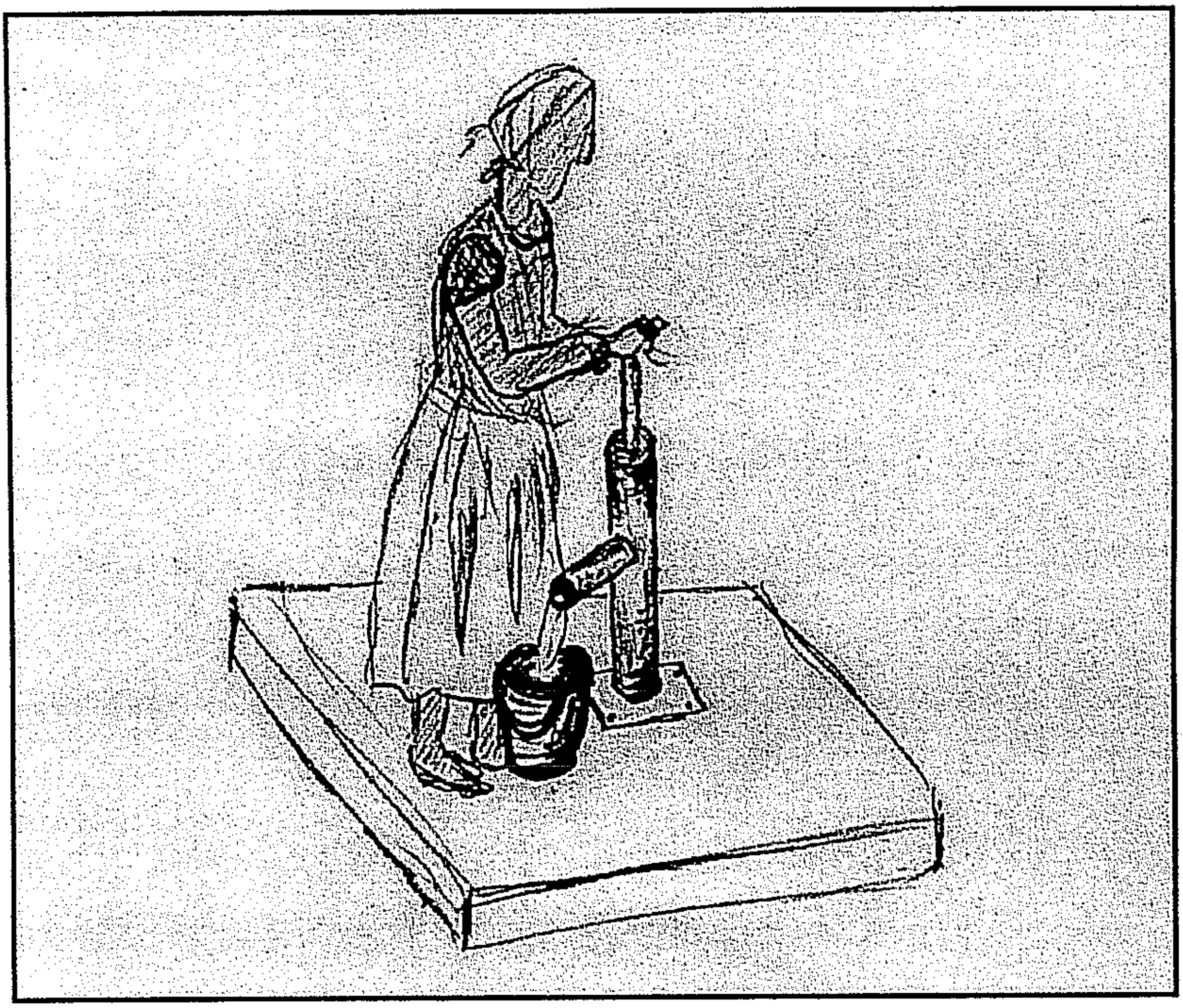
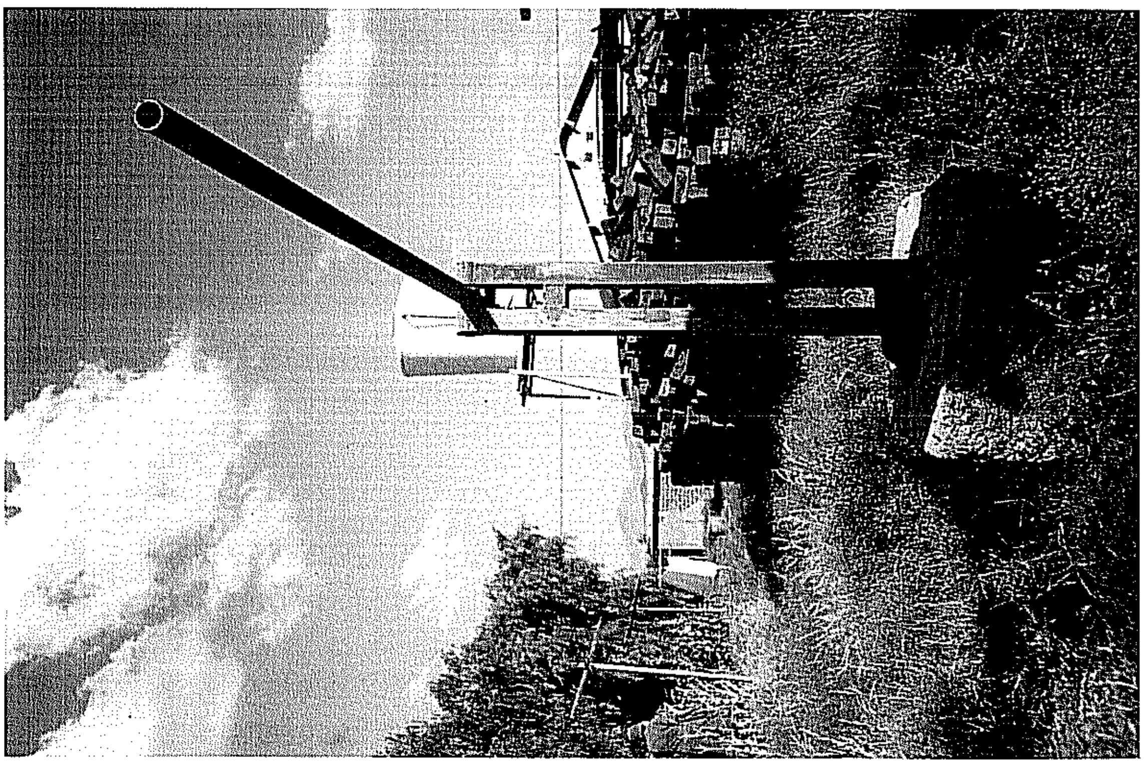


4.1

ANNEXURE F

Pump1

Pump 2

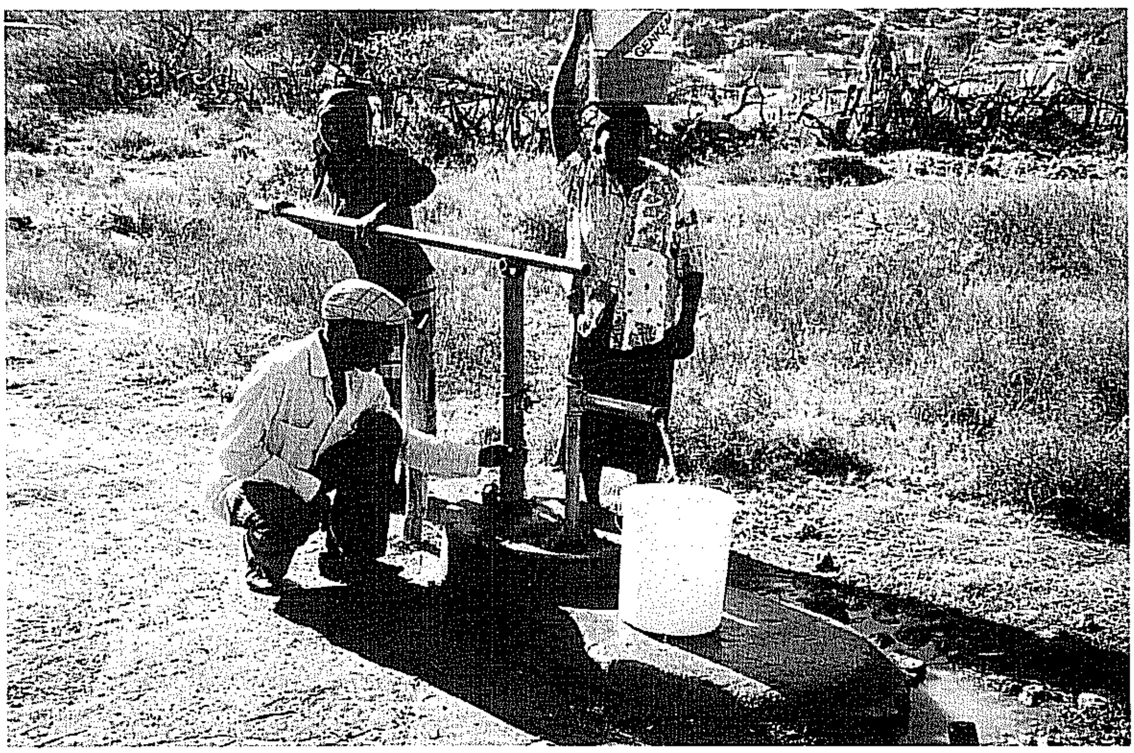


Pump 4

Pump 5

Pump 7

Pump 12



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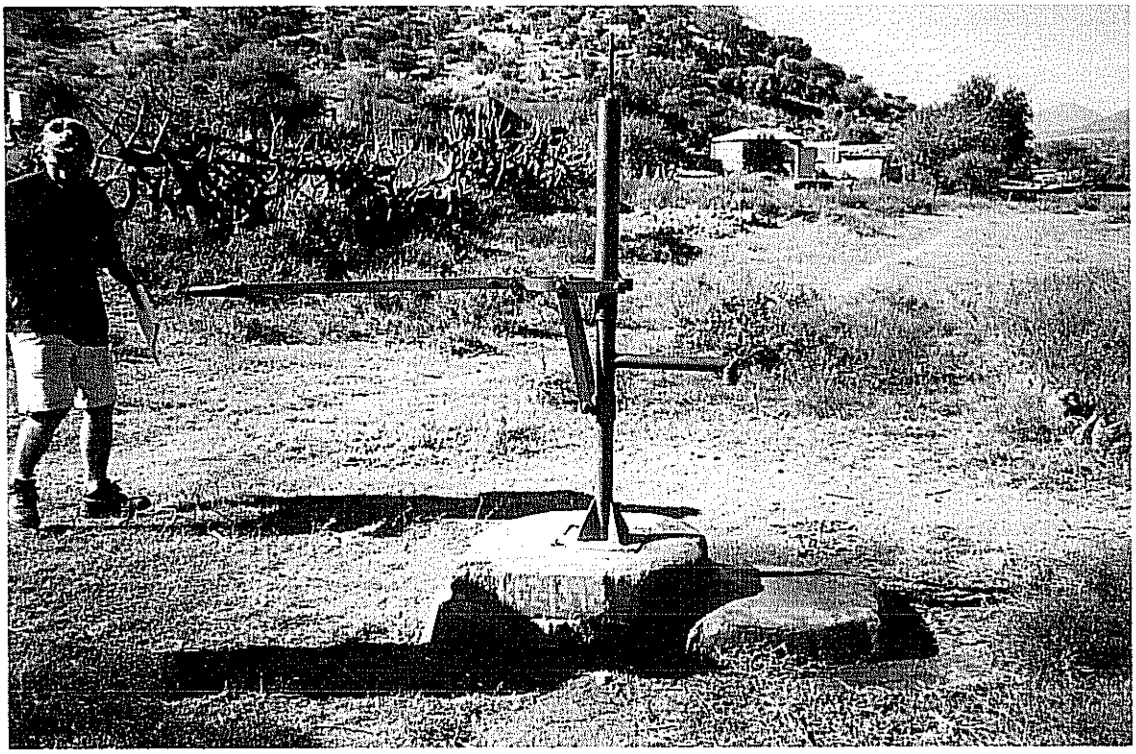
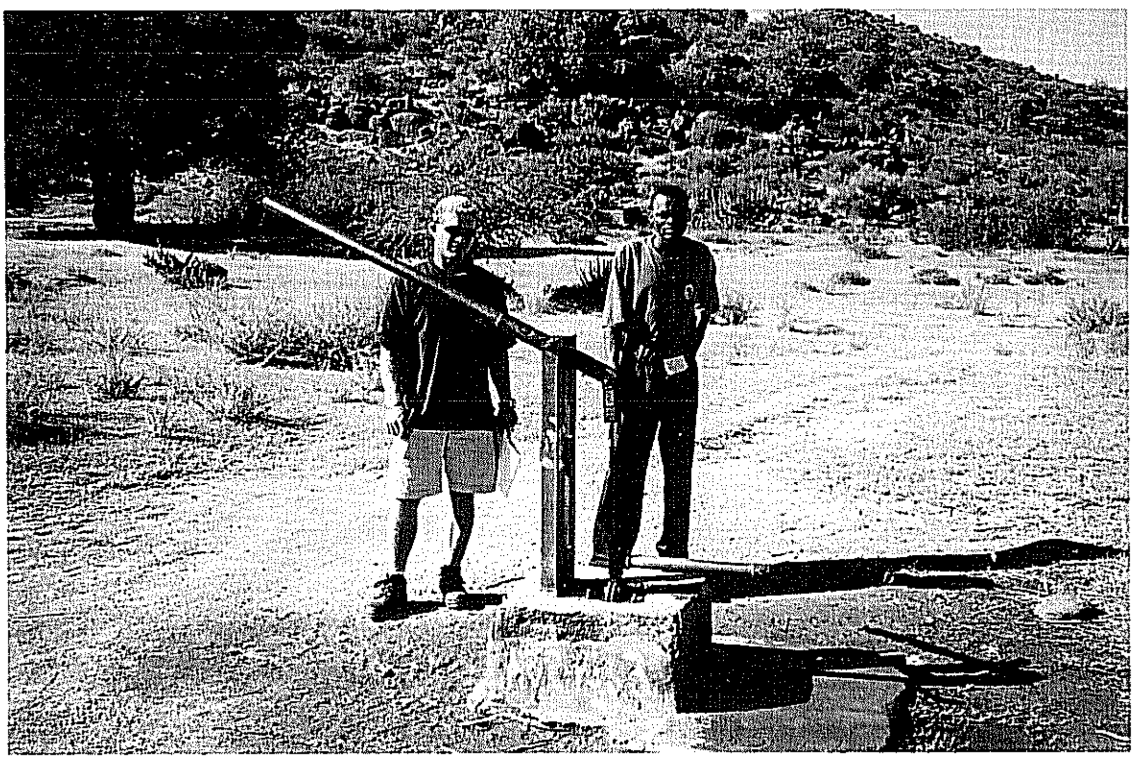
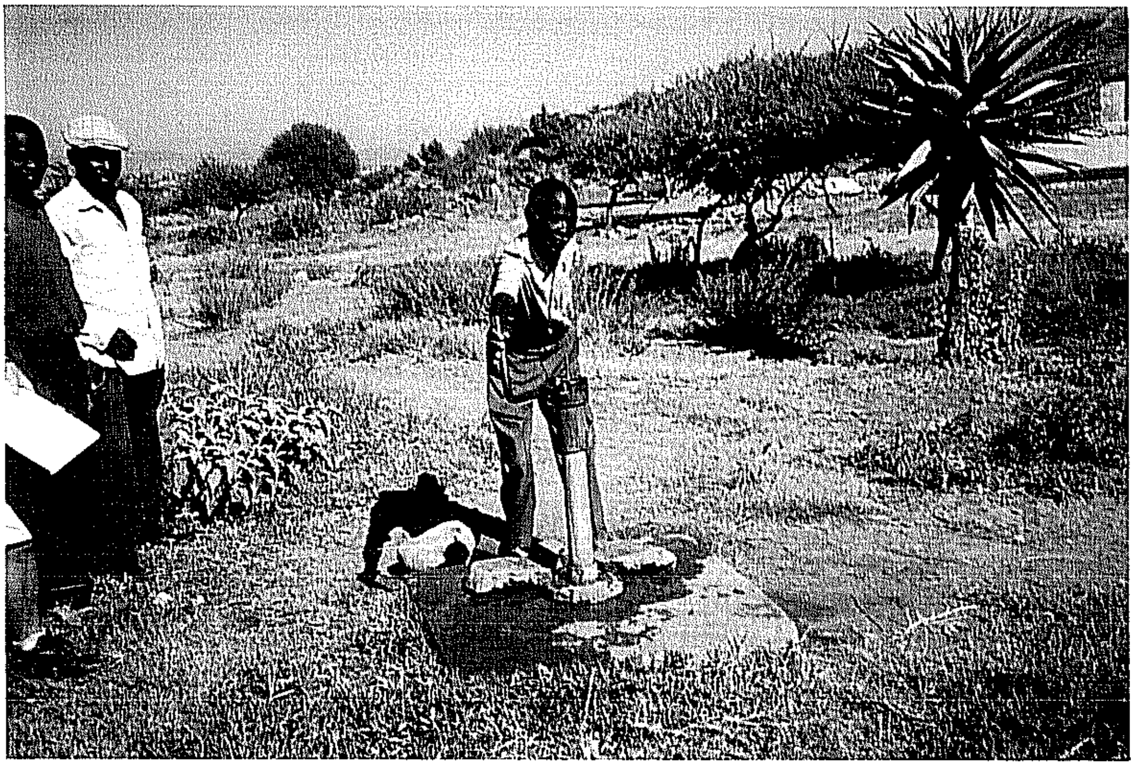


Pump 14



Pump 15



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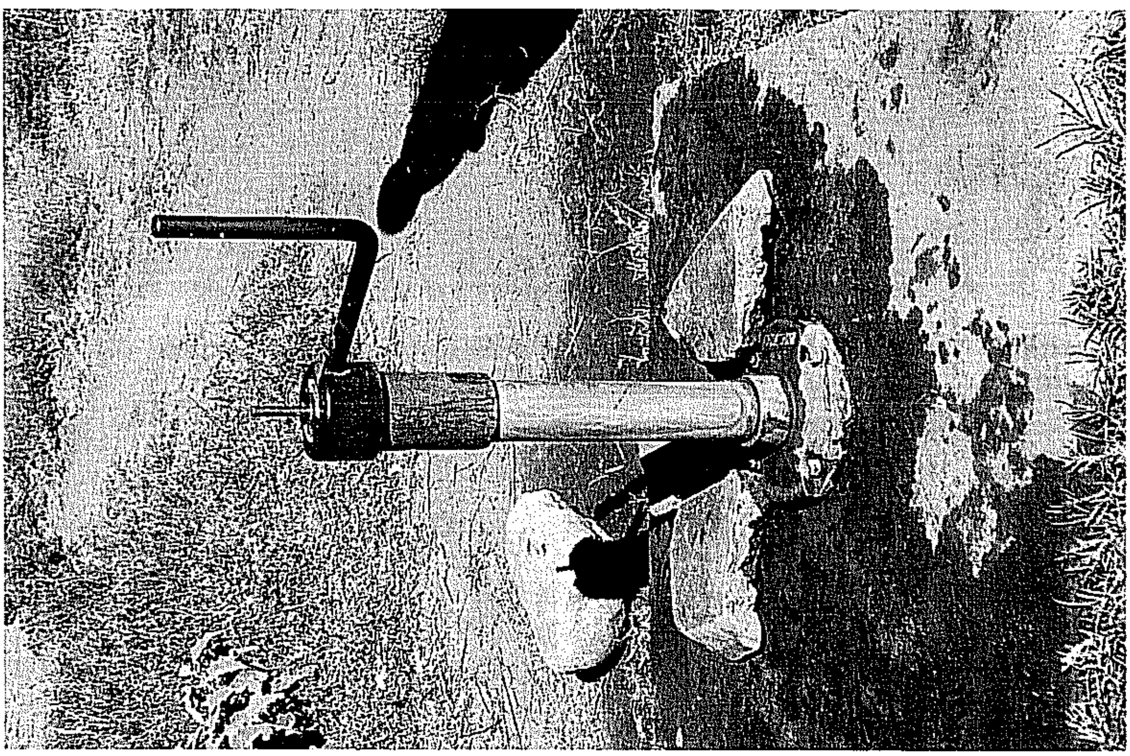

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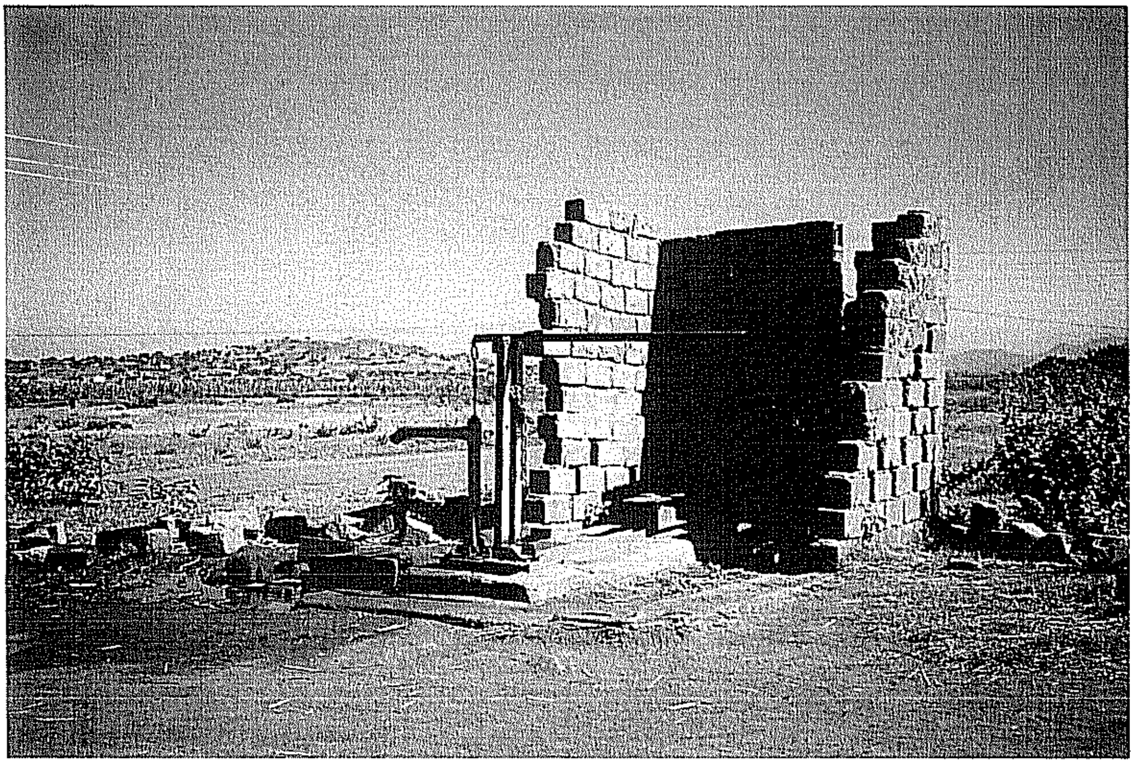
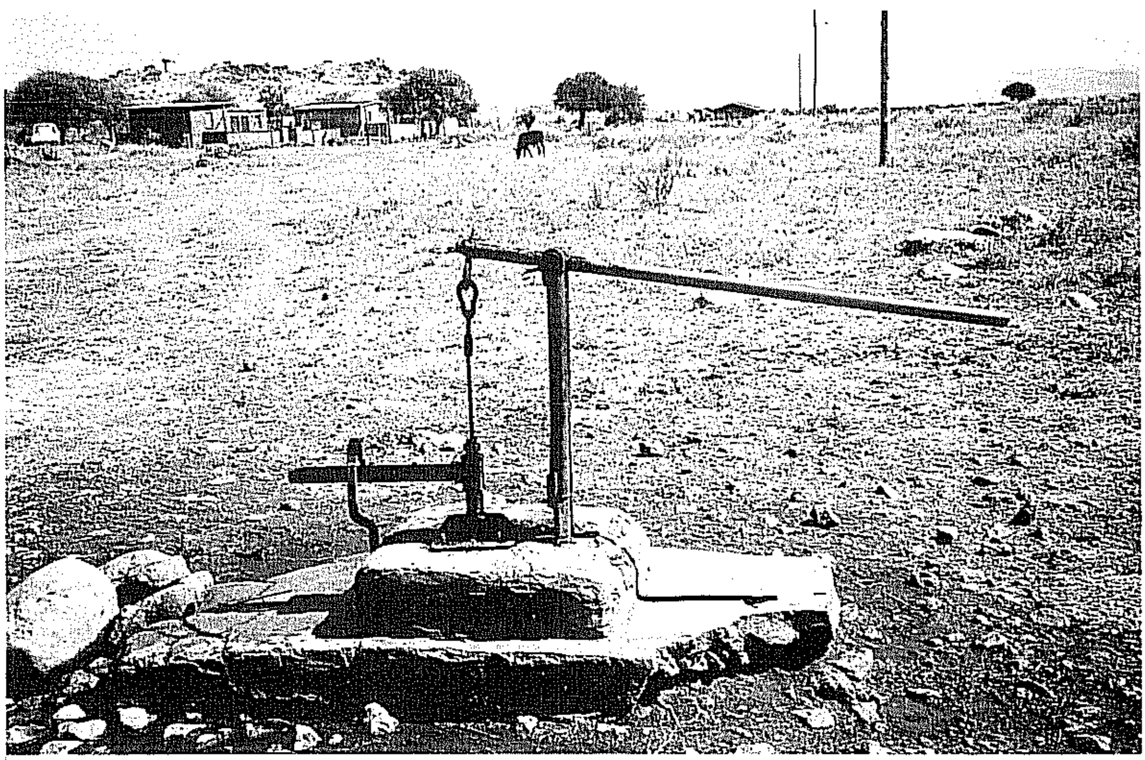


Pump 17

Pump 18

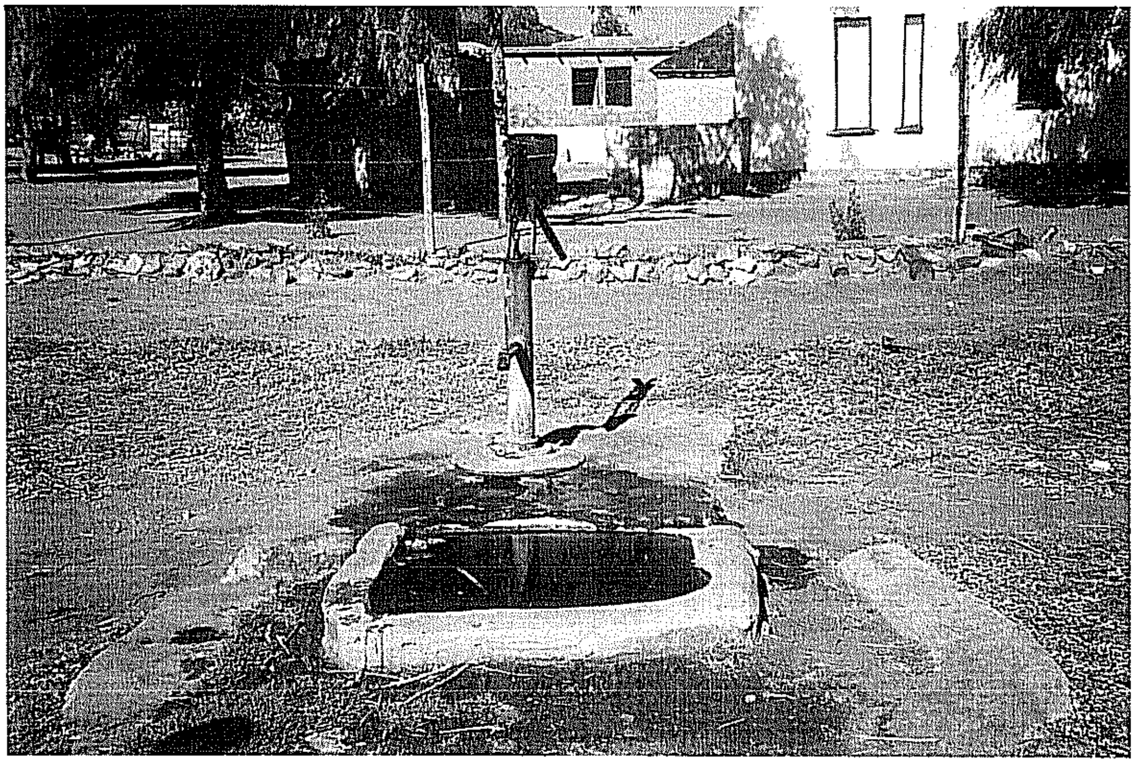
Pump 22



Pump 25

Pump 28

Pump 34



Pump 43