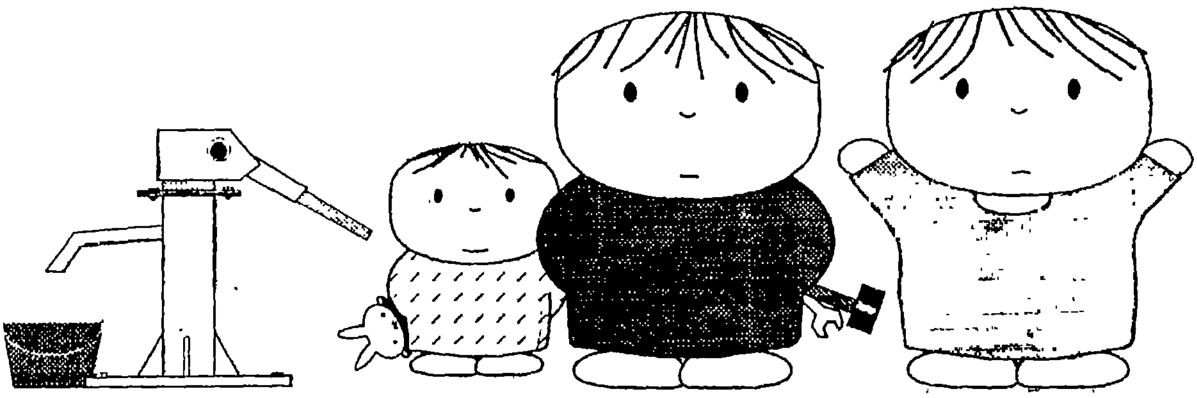
RURAL WATER SUPPLY WITH HANDPUMPS

Reconsideration of Village Level Operation and Maintenance Its Possibilities and Limitations



Albert Buitenhuis

Wageningen Agricultural University October 1993

Department of Irrigation and Soil and Water Conservation

RURAL WATER SUPPLY WITH HANDPUMPS

Reconsideration of Village Level Operation and Maintenance Its Possibilities and Limitations

Albert Buitenhuis

Wageningen Agricultural University
Department of Irrigation and Soil and Water Conservation

October 1993

PREFACE

This paper contains the outcome of my research on the Village Level Operation and Maintenance concept, and on the existence of VLOM-handpumps for wells with static water levels deeper than 45m. This research leads to the M.Sc. degree in Tropical Land and Water Management, and has been done at the Department of Irrigation and Soil and Water Conservation of the Agricultural University of Wageningen.

At the moment of this writing, it is about one year ago that I received the request for the research on VLOM-handpumps for such extra-deep wells. It is my conviction that this report highlights some key-issues considering the sustainability of handpump supplies. Real sustainability can only be effected if implementors approach rural water supply projects from the community development point of view. It can not be effected by the instalment of handpumps only, but should go hand in hand with training, education, motivation.... Such development, taking lots of time, might require a shift away from production goals. It is better to implement a few sustainable systems, than implementing lots of systems failing sooner or later. The report makes clear that maintenance systems, in which all maintenance is performed on the local level, are unlikely to be sustainable; at least for the time being. Sustainability might require long term external assistance in maintenance.

Most of the research has been done in the Netherlands -a desk study-. To get practical insight, I went to Ethiopia for about one month. There I visited and researched the 'Water Programme' of the Kale Heywet Church Development Programme. In order to complement the KHC efforts to share the Living Water, being Jesus Christ, for all Ethiopians, this NGO has set up the Water Programme to attend to the need for actual physical water. It is in this period, that I became aware of the need for sustainable water supplies, and learned to know some practise of water supply in rural areas. I learned to *feel* the need for clean water, for sustainable supplies: something one cannot get from paperwork only. Therefore I am still thankful for the opportunity I had.

To give thanks to all the people that advised and supported me during this research would be too much. So many people showed their interest. But I want to mention some names.

First of all I want to thank my wife, for her love and support. You allowed me so much time studying.. You learned to know 'Africa', discovered this other world of reality, and learned to appreciate it. Thanks for your wonderful idea about the front cover! I want to thank my parents; they made our journey to Ethiopia financially possible. I want to thank my parents in law, and all our friends, brothers and sisters for their sympathy.

I want to thank Tear Fund- The Netherlands. They sent my request for a research on community water supply to Daniël Schotanus, and Daniël offered me this opportunity. I want to thank him for his guidance in Ethiopia, and want to thank both Daniël and Alice for their friendship and hospitality. We'll not forget you with your little zoological garden, and the trips we made. Thank you, all people at the KHCDP, especially dr. Malatu, Desta, but also Gezahyn and Getachew, with whom I went into the field. I hope you'll enjoy your 'triominos' for lengths of time.

At the university, I want to thank Geert van der Knaap and especially Arie Bons for their guidance and useful comments, for discussing the many concepts, draft reports, and views, for bringing to light the shortcomings, and for their interest in the research. It has been nice to have such tutors.

I want to thank the people at the IRC in The Hague, for their support and help in the procurement of documentation, and opportunity I had to come there that several times.

Most of all I want to thank my Father in heaven. Your love reaches out to all mankind, over the whole earth; also to the rural poor in third world countries. You don't want no death, illness, or disease. In Jesus Christ You showed Your endless love and compassion. You gave us responsibility for this world, and taught us to love our neighbour.. also in third world countries. Forgive us our shortcomings and make us what you want us to be. We want to follow You.

"*They will hunger nor thirst, for He, who has pity on them,*
will lead them to springs of water". (Isaiah 49:10b)

Capelle aan den IJssel, October 1993

Albert Buitenhuis.

CONTENTS

1	INTRODUCTION	1
2	RURAL WATER SUPPLY WITH HANDPUMPS	3
2.1	History	3
2.2	The International Drinking Water Supply and Sanitation Decade and the Handpumps Project	4
2.3	The concept	8
2.4	Performance and management of maintenance	11
2.5	The present situation	13
3	THE SOFTWARE	14
3.1	Policy	14
3.2	Planning and implementation	14
3.3	Timing	15
3.4	Monitoring and evaluation	16
3.5	Preventive maintenance	17
3.6	Recurrent costs	17
3.6.1	Maintenance costs	17
3.6.2	Replacement costs	19
3.7	The covered geographical area	20
3.8	The settlement pattern	20
3.9	Spare parts distribution	21
3.10	Actors	22
3.10.1	The interface	22
3.10.2	Agency personnel	23
3.10.3	Community members	23
3.11	Local factors	25
3.12	Enforcing local traditions and technology	25
3.13	Community management	25
3.14	Community participation	29
4	THE HARDWARE	31
4.1	Introduction	31
4.2	Handpumps	31
4.3	Reliability and maintainability	34
4.4	Maintainability	36
4.4.1	Accessibility	36
4.4.2	Standardization of components	39
4.4.3	Local manufacture	39
4.5	Examples of handpumps	41

4.5.1 The India Mark III concept 41
4.5.2 The Afridev concept 43

5 VLOM: TO WHICH EXTENT? 45

5.1 Introduction 45
5.2 A comparison with other maintenance systems 46
5.3 The right balance 50

6 HANDPUMPS ON EXTRA-DEEP WELLS 53

6.1 Technological backgrounds 53
6.2 Nature of the problems 54
6.3 The existence of extra-deep wells 55
6.4 Handpumps on extra-deep wells? 56
6.5 VLOM of extra-deepwell handpumps 56
6.6 The use of plastic risers 57
6.7 Extra-deep well handpumps 60
6.7.1 The Aquamont 60
6.7.2 The extra-deepwell India Mark II 61
6.7.3 The Kardia 62
6.7.4 The Mono 62
6.7.5 The Moyno 63
6.7.6 The Pulsa 63
6.7.7 The SWN81/90 64
6.7.8 The Vergnet 4C/4D 65
6.7.9 The Volanta 66
6.7.10 Pump selection 67

7 CONCLUSIONS 71

BIBLIOGRAPHY 74

APPENDIX 1: The CRL testing programme
2: The Vergnet handpump
3: The Volanta handpump
4: Addresses of manufacturers of extra-deepwell handpumps

Illustrations in this report have been derived from 'the Afridev Handpump' (UNDP/WB,1987); illustrations of the different pumptypes in chapter 8 are derived from 'the Handpump Compendium' (Arlosoroff,1987), except for the illustration of the extra-deepwell India Mark II (BIS,1992).

FIGURES

1:	Approaches to maintenance problems	4
2:	Systems map of the package of partial self-reliance	5
3:	The IDWSSD-targets	6
4:	Numbers of people in developing countries, without access to safe drinking water, during the IDWSSD	7
5:	The VLOM-concept	10
6:	A categorisation of maintenance systems	12
7:	Options for organizing spare parts procurement and distribution	22
8:	Local factors of importance considering VLOM	26
9:	Local knowledge and traditional management in some African examples	27
10:	Approval or rejection of community managed maintenance systems, on base of the community level and community development	28
11:	Different pumptypes	34
12:	An outline of piston pumps	33
13:	The reliability of handpumps as determined in two examples	35
14:	Repairs by part type	37
15:	Installation details of the India Mark III handpump	42
16:	Active repair times of the India Mark II and -III pumps	41
17:	Maintenance regimes, India Mark II and -III pumps	41
18:	An outline of the Afridev design	44
19:	A comparison of three categories of maintenance systems	47
20:	A comparison of VLOM and non-VLOM maintenance systems	48
21:	A comparison of management systems as analyzed by Besselink	49
22:	Indicative sketches of the performance of VLOM and centralized maintenance over time	52
23:	Pumping lift frequency distribution in field trials of the Handpumps Project	55
24:	Pumping lift frequency distribution in field trials of the Handpumps Project	55
25:	Swinging and snaking of μPVC rising mains	58
26:	Stretching and relaxing of μPVC rising mains, consequently the loss of volumetric efficiency, and its relation to riser length	58
27:	Fractures in the cemented riser joint of the Volanta, occuring at deep installation.	59
28:	Estimated discharge rates of several extra-deepwell handpumps, as a function of the SWL, at a power input of 100W	67
29:	Rating table of the different extra-deepwell handpumps	68
30:	The share of different handpumps used in Ethiopia	69

1 INTRODUCTION

Safe drinking water is one of the most important needs of humanity. The extent and quality of drinking water supply in western countries is contrasting to the deficiency of the supply in third world countries. Because of the quality and quantity of water from traditional sources, water borne and water washed diseases are common, resulting in high mortality and sickness rates. In urban areas, but far more in rural areas, a basic need for safe water -and sanitation- exists.

It is for this reason that the past decade has been called the 'International Drinking Water Supply and Sanitation Decade' (IDWSSD; 1981-1990). It has been the intention to provide safe water and adequate sanitation for all by the year 1990. This objective has not been reached. According to some authors this had to be expected: but everyone will agree, that it is a pity. The Decade has been prolonged; the intention now being to reach the goals by the year 2000.

The handpump option is one of the options to improve rural water supplies. Although attitudes have been different, handpumps are widely considered to be the most affordable means for improving rural water supplies nowadays. The reliability of handpump schemes has left much to be desired in the past. Publications, mentioning that up to 80% of the handpumps were out of order due to a lack of maintenance, made clear that something had to be done on the issue of handoump maintenance (Falkenmark,1982).

For this reason the United Nations Development Programme and the World Bank started their Handpumps Project. This project was initiated in 1981, as one of the activities in support of the IDWSSD. Its main objective has been to promote the development of designs and implementation strategies which would improve the reliability of schemes based on groundwater and handpumps, and which would enable schemes to be managed by the communities and replicated on a large scale. It has been an early conclusion of this project that involvement of the user community in maintenance was essential for successful drinking water supply projects. For this reason the term 'Village Level Operation and Maintenance' (VLOM) has been coined (Arlosoroff et al,1987). Village Level Operation and Maintenance, being an approach in which the user community is responsible for the maintenance of its handpump(s), is widely recognized to be the only affordable maintenance strategy. But to effect such a maintenance system is certainly no piece of cake. And whether such a system can be used to maintain handpumps to full extent and in all cases, has to be questioned.

The VLOM-concept brings about guidelines: not only about hardware (design criteria for handpumps), but also about software (such as community education and organizational aspects about the implementation of handpumps projects). However, the design- and selection criteria of the hardware are the main guidelines in the concept.

Although some authors question the essence of the problem, maintenance seems to be obstructed with increasing depth of the static water level (SWL). Especially when the SWL is beyond 45 meters (in literature often called *extra-deep wells*), serious problems occur; such as difficulties in lifting below ground components due to the weight of the installation, fatigue of materials, decreasing efficiency and stroke of the pump, and increased maintenance needs. The deeper the SWL, the fewer the number of pumps suitable to lift water from such depths; the more expensive the installation; the less possibilities for Village Level Operation and Maintenance and to effect a sustainable drinking water supply (Arlosoroff,1987).

This report is the documentation about my research on the above mentioned issues. The objectives of the research have been twofold:

1) Firstly, to research *what is meant by the VLOM-concept*; and whether VLOM is a practical guideline for maintenance.
2) Secondly, to research *whether there exist handpumps, which can lift water from Static Water Levels up to 100m and which are suitable for Village Level Operation and Maintenance*.

I received the request to research the second question from the Kale Heywet Church Development Programme (KHCDP), a Non Governmental Organization (NGO) in Ethiopia that works on rural water supply. 36% of the productive wells drilled by this organization have SWLs beyond 45 meters. The NGO is in need of a suitable VLOM-handpump to lift water at these wells.

Chapter 2 (Rural Water Supply With Handpumps) is an introductory chapter, discussing backgrounds of VLOM, the VLOM concept itself, and the distinction in both software and hardware. Software and hardware are discussed in chapter 3 respectively chapter 4. I will discuss the extent to which VLOM can possibly be effected in chapter 5. Chapter 6 deals with the second question of the objectives; VLOM-handpumps on extra-deep wells. In chapter 7 I will summarize the most important conclusions of the report.

Practises of rural water supply in developing countries, as existent today, are the base of the report. It is my hope that this report results in a reconsideration of rural water supply; a growing awakening of the limitations of technology, the importance of building forth on local knowledge and wishes, and, especially, in a growing awakening that the factor 'time' should never be eliminated or neglected in implementation.

It has certainly not been the intention to give some 'blue print' approach to the mentioned issues and their features. It has been my objective to describe that issues, that occur frequently in the practise of rural water supply. Whenever possible, I want to illustrate them with practical examples. Most of this report refers to the African context, but I am convinced that much of the mentioned issues have their reference with other -non African- developing countries too.

This report is more or less unique in that sense that it discusses both the pro- and contras of Village Level Operation and Maintenance. Different from previous publications on the subject, the report is not written to promote or slate VLOM. It rather gives an insight in the prerequisites for VLOM. Different possibilities and constraints of VLOM, which should be known prior to effecting sustainable maintenance systems, are summarized.

2 RURAL WATER SUPPLY WITH HANDPUMPS
2.1 History

When the need for improved rural water supply systems in third world countries came into the focus, this had first been considered as a rather technical matter only. The first efforts to improve the rural water supply systems originate from the sixties, although it did not receive full attention until the seventies. It is also in this last mentioned decade that village water supply with handpumps came forward as an affordable solution.

Pacey is the first author that recognizes maintenance problems with handpumps (Pacey,1977). His analysis has been on the basis of many other publications on handpumps maintenance. Therefore I want to deal with his analysis extensively.

Pacey makes notice of the huge number of handpumps broken down after a few years of operation. He mentions cases where up to 60% of the pumps were out of order in the case of deepwells (in that time defined as wells with a SWL $\geq$ 8 meters), while there obviously seemed to be a positive correlation between SWL and the broken down percentage of handpumps. These handpumps were -more or less- 'copied' versions from handpumps formerly used in western countries. These pumps however were not designed to bear the harsh conditions such as exist in developing countries: heat, dust, very intensive use, and poor maintenance. Whenever these pumps were manufactured in the developing countries, they additionally were of a (very) low manufacturing quality. Pacey underlines the importance of new pump designs, especially designed to be used in developing countries; and quality control. Next to this, he makes clear that it is not to be expected that technology alone will solve all problems. He approaches the problem also by analysing the communities, the agencies involved, the objectives for which the wells were provided and the environment: an summary on his analysis is given in Figure 1. Pacey mentions the importance of the appropriateness of all these factors, as is intermediate technology, but also of social and environmental appropriateness, as well as appropriateness from the health point of view. While the concept of intermediate technology basically is an economic one, making maximum use of local resources and requiring only an intermediate or low capital investment, overall appropriateness obviously implies more than that (Pacey,1977; Pacey,1980; Bron,1985). One could speak about the appropriateness of projects. An appropriate project will -in practise- compromise all mentioned factors (Bron,1985).

Because of the importance of appropriateness in its broadest sense, Pacey *rather* talks about *investigating packages than* about *investigating technology solely*. In this way a distinction can be made between three packages.

- The first, in which there is a *total self reliance* of communities in the manufacture and maintenance of the pumps. The pumps are of a traditional design, or are copied versions of western pumps, and only capable to lift water from shallow water levels.
- Secondly, a 'package' of *partial self reliance*, with factory made pumps, but with villagers at least partly responsible for maintenance. The pumps used in this package should be suitable for such a system: it should be possible to maintain them easily by people with few skills. Some backup service is needed which would supply spares and would inspect the pumps

Approaches to Maintenance Problems
The communities using the wells and pumps:
✓ Do the communities appreciate the benefits of using well water?
✓ Do they feel the pump is theirs?
The agencies administering well projects:
✓ Construction and Maintenance should not be separate operations
✓ Maintenance should also include preventive maintenance, next to repairs only
✓ Records should be kept of every pump visit
✓ Pumps should be standardized
✓ There budget should be large enough to employ skilled manpower and to pay transportation costs
The objectives of well projects:
✓ The objectives should be classified as development project; long term considerations should be taken
The environment:
✓ The siting of a well should in first instance be where the villagers want it
✓ The aquifer should carry enough water with a satisfactory taste

Figure 1: Approaches to maintenance problems (Pacey,1977).

regularly. Because of the village responsibilities such a package should include some community development in every case.
- Thirdly, a 'package' *eliminating all village responsibility*, in which the pumps are provided and maintained without participation by the users. Such a package should be supplied in that cases in which normal maintenance could not be guaranteed. A kind 'maintenance-free' or low-maintenance-handpumps should be used, such as the MONO, or the Jalna handpump out of which the India Mark II has been developed later (Pacey,1977).

Pacey denotes that the second package is the most promising one. A system map of this package such as regarded by Pacey is given in Figure 2. Although Pacey does not define a maintenance system like VLOM, it is remarkable that he defines a number of 'packages' that are similar to present maintenance systems in a large extent. Much of the mentioned key-issues, considering the maintenance problems, correspond with issues mentioned in the VLOM-concept -such as published by the United Nations Development Programme (UNDP) and World Bank (WB) in 1987 (Arlosoroff et al,1987; Pacey,1977; Pacey,1980).

Of course problems have not been overcome directly since, or as a result of, this publication. But Pacey's publication forms the basis of the present way of thinking, considering maintenance of handpump systems.

2.2 The International Drinking Water Supply And Sanitation Decade and the Handpumps Project

As the conviction grew that rural water supply in developing countries was of primary importance for the health of millions of people, several international conferences, workshops and seminars have been organized on this subject.

The International Drinking Water Supply and Sanitation Decade grew out of the

World Water Conference in Mar del Plata, Argentina, which was held in march 1977. The subject of this conference had been the relation between the lack of safe water, infections and high child mortality in developing countries (Falkenmark,1982).

In the general assembly of the United Nations on 10-11 november 1980, the UN designated the period from 1981-1990 as the International Drinking Water Supply And Sanitation Decade. The slogan for this Decade has been 'Safe Water and Adequate Sanitation for All by 1990, if possible'. The exact objectives, as given by Falkenmark, are displayed in Figure 3. The World Health Organisation (WHO) has been the decade leader.

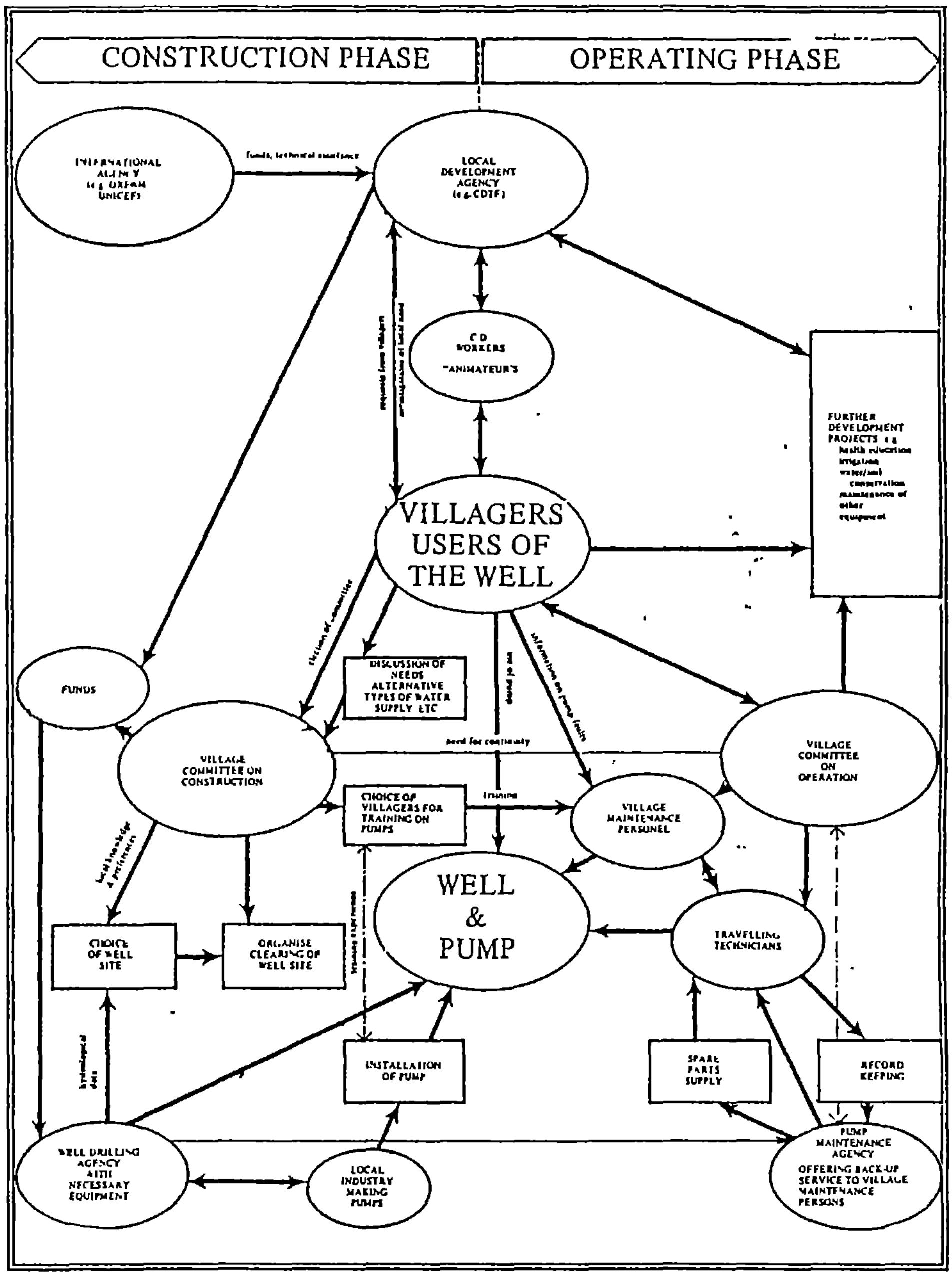


Figure 2: Systems map of the package of partial selfreliance (Pacey,1977).

Besides the Primary Health Care (PHC) objectives of the decade, the decade intended to revolutionize the role of the rural women. It was felt that they were stressed by an enormous labour burden. By diminishing the time needed for water collection and the modernization of women's role in rural water supply more time for other profitable activities had to be made available. In this way the number of productive people would also increase, responding to the need of economic development (Falkenmark,1982).

The possibility to reach this goals by 1990 has ever been questioned since the designation of the decade (Bron,1985). To reach the goals some 2000 millions of people

Water Supply	urban	100%
	rural	100%
Sanitation	urban	100%
	rural	30-50%

Figure 3: the IDWSSD-targets (Falkenmark,1982).

would have to be supplied. Falkenmark mentions that at least two million wells would need to be drilled or dug; which is probably a low estimation, as an average of 1000 users per handpump seems far too much in practise. This number has probably to be doubled at least. In fact 500.000 people would have to be given new or improved water supply systems every single day (Falkenmark,1982). Costs involved to provide the necessary services have been estimated to be as much as US$ 200-500 billion (Bron,1985; Falkenmark,1982).

One could question the correctness of the IDWSSD-objectives. I want to mention three points which are of importance in this report.

Firstly a kind of 'pressure' has been created to reach the goals within a time much too small. It seems like the factor 'time' is being eliminated, or that time needed to reach such goals can be controlled completely.

Secondly, it is implicitly assumed that rural communities want an improved rural water supply and sanitation system, or that it is at least possible to convince them of the urgency of an improved water supply and sanitation. But what if rural communities do not agree, if they do not feel such a need? Can 'education' always correctly be used as a means to convince people? We have to realize that we are talking about the rural communities' development; and that *their* view and wishes are the determining ones. This is also the case with goals like the 'revolutionization of women's roles', 'modernization' and 'reaching economic development'. Such subjects so far only reflect *our*[1] view of development needed, while *their* view and wishes are the determining ones: at least on the long run!

Thirdly, the objectives of the IDWSSD implicate that an improvement of rural water supplies and sanitation is always possible (or desirable); But what if the prerequisites of a sustainable water supply or sanitation works cannot be fulfilled?

The objective of the Decade has not been reached. The World Bank's publication 'Community Water Supply; the handpump option' already indicated the needed prolonging of the decade, as a result of the disappointing progress, in 1987 (Arlosoroff et al,1987). Figure 4 might illustrate this. Probably the mentioned figures are still too positive, because there has not been dealt with supplies out of use due to (permanent) breakdown (Bron,1985). It is still to be questioned whether the renewed IDWSSD goal is within reach. A considerable increase in national spending and donor funding would be needed at least.

The UNDP/WB handpumps project (the Project) has been initiated in 1981, as a major contribution to the IDWSSD. Its main objectives have been to promote the develop

[1] 'Our', i.e. researchers on the subject; agency staff

	1980			1985			1990		
	population	unserved	%	population	unserved	%	population	unserved	%
urban	990	376	38	1200	400	33	1446	463	32
rural	2380	1645	69	2500	1500	60	2614	1514	58
TOTAL	3370	2021	60	3700	1900	51	4060	1977	49

Figure 4: Numbers of people in developing countries without access to safe drinking water (in millions of people) during the IDWSSD, according to Besselink (1992).

ment of designs and implementation strategies which would improve the reliability of schemes based on groundwater and handpumps, and which would enable schemes to be managed by the communities and replicated on a large scale (Arlosoroff et al,1987). The Project contributed to set quality and ergonomic standards as well as defining appropriateness for handpumps (Bron,1985). The VLOM-concept came out of this Project as a basic principle for the maintenance of rural water supply systems supplied with handpumps. To create an awareness of the importance of VLOM there have been organized workshops worldwide.

In september 1990 new agreements have been made on the subject of water and sanitation (WatSan). This resulted in the New Delhi Statement. This statement reflects the present way of thinking towards water and sanitation, and contains the following factors:

✓ the protection of the environment (the need for a integrated management of water resources)
✓ institutional reforms (the need for an integrated approach with other developments, a change in procedures, attitudes and behaviour, and the participation of women in water and sanitation projects.
✓ community management of services (the need for a strengthening of local institutions)
✓ sound financial practises (the need for a better management and appropriate technology) (UNDP,1990)

Basically two things might happen to accelerate the improvement of water supplies worldwide:

1) more resources might be used, such as financial resources, manpower.
2) the planning and implementation stage might be accelerated.

There has been an increase in the expenditure on rural water supply activities during the Decade. But because the resources available are limited, acceleration of the planning and implementation stage is order of the day. Resulting in supplies in which has been economized on the *software*: the non-material contents of interventions. Agencies, implementing in such a way, will surely write in their annual evaluation papers about the number of handpumps installed or the number of people supplied, but on the long term success, or even operation, can surely not be guaranteed. When handpumps break down and users go back to their contaminated traditional supplies, the ultimate result might be worse than when nothing had been done at all: the resistance against diseases diminishes when people are going to use clean- in stead of contaminated water. Whenever users (have to) return to the contaminated supply, this might result is severe illnesses, worse than ever before, or even death (Cairn-

cross,1988). Next to this, it is important to ensure that communities continue to rely upon supplies, because the psychological impact of inoperative handpumps is very negative. Community members might never want future interventions anymore, because of bad experiences with past interventions that failed. Some authors argue that the psychological impact will be limited once a handpump has been in operating conditions for two years. Of course this is an average; in practise the impact of breakdowns will differ from place to place. Schoolkate argues that a negative attitude towards handpumps might easily develop if they break down too frequently, or if they do not have water at the end of the dry season (Bron,1985; Hofkes,1987; Schoolkate,1991).

2.3 The concept

Where people live, there has to be water at some neighbouring place. Otherwise there would not have been people at all. Such traditional water supply systems do need maintenance; even if this implies replacements of buckets or other devices to carry water from the river homewards only. Traditionally, *all* maintenance is performed on the village level.

The importance of Village Level Operation and Maintenance therefore only becomes evident in cases in which some external intervention took place to change traditional water supply systems. Be it the upgrading of a traditional well, the installation of a handpump on a well, or any other water delivery system.

From the development point of view, improved water supplies, such as handpumps, should be sustainable. Otherwise one could not speak about progress; improvements would be worthless on the long run. This sustainability is the most important reason why maintenance -especially VLOM- needs attention.

The 'village level' of the Village Level Operation and Maintenance concept rather reflects the residence of the people responsible for the maintenance tasks, than the location where maintenance is performed: maintenance will almost always be performed at local level, even when it is performed by centralized maintenance teams.

The essential part of the VLOM-concept lies within the 'M' of the concept: *M*aintenance. Wierema mentions the following definition of maintenance: "*Maintenance compromises those activities meant to either keep objects over which an actor disposes, in the condition, or bring them back in the condition deemed necessary for fulfilling the function as defined by the actor*" (Wierema, 1987). Bron has called maintenance 'the headache of the decade', not aiming at problems in the instalment of handpumps, but in their maintenance (Bron,1985).

We could speak of Village Level Maintenance (VLM) only. But because the maintenance of handpumps should be inherent to their operation, it is important to keep the 'O' within the concept. Too often operation and maintenance have been seen as two rather separate activities: a pump is operational for some time, because it meets its requirements; and when it breaks down maintenance has to be performed. But in fact one could not speak about maintenance in such cases, but about *repair. Maintenance is not only needed when a pump is broken down* (repair; cure), *but the more to keep it operational* (preventive maintenance).

It are mainly the -on the long run unbearable- costs of centralized maintenance systems which have been the reason for the attention given to VLOM.

Often governments are left with the so-called 'golden handshake' -the responsibility

for maintenance (costs) of handpumps installed by foreign agencies. When the number of handpumps is increasing, the maintenance sooner or later becomes too expensive: largely because of the transportation costs, which are inherent to centralized maintenance. Centralized maintenance of handpumps is therefore not feasible on the long run. In fact, the same is true considering NGOs.

Therefore ways have been sought to reduce the need for expensive centralized maintenance teams. It was believed that the costs could be lowered rigorously by a greater involvement of communities in maintenance: a shift from centralized to -more- decentralized maintenance (Arlosoroff,1987). This would also limit the maintenance costs caused by negligence and ignorance of the communities (Wilgenburg,1991). Existing reliability problems would be solved largely by a shift towards VLOM.

Was it the original intention of the Project to develop a new generation of handpumps, after the importance of VLOM became clear, it has additionally become the intention to design handpumps for maintenance by village caretakers (VLOM). The Project has primarily aimed at this hardware-side. Next to the hardware side, the VLOM concept includes software elements, and extends into the institutional arrangements needed to ensure that skills, tools and spare parts are available when needed. Therefore the term VLOM has been expanded to mean village level *management* of maintenance. Management of handpumps has been found crucial to the long term sustainability of supplies (Arlosoroff et al,1987; Reynolds,1992). An outline of VLOM, as published by the United Nations and World Bank is given in Figure 5.

Maybe it has to be wondered whether the cost aspect of maintenance is the right reason for a shift towards VLOM. Would maintenance have remained the responsibility of centralized institutions when costs would not have been problematic at all? From the development point of view, as much as possible should be directed to the village level. According to me, such a shift in (management) of maintenance responsibility should already be made because the dependency relations would be minimized. This is a positive fact, as it can never be guaranteed that donations from western countries or governments keep on coming; while it *can* be guaranteed that the need for water remains. Unnecessary dependency on external organizations should not be created. What if a project, or a NGO, would not exist anymore? What if all external or foreign support would fall back? VLOM offers the best perspective. VLOM should not only be considered as a means to save agencies' wallet's content, but also as a right of the community; an ultimate goal of development.

THE VLOM CONCEPT

An early conclusion of the UNDP/WB Handpumps Project was that strong involvement of the user community in maintenance was essential for successful projects. The Project coined the term VLOM- Village Level Operation and Maintenance- as a means of bringing home to handpump manufacturers and users the key issue in solving widespread problems experienced with centralized maintenance.

Experience in one country after another has shown that a central maintenance system, requiring a motor vehicle and crew to move out from a base camp, is unable to keep pumps in satisfactory operating condition. The large expense of such maintenance and the logistical and staffing needs to supply enough experienced and motivated teams of mechanics to carry out repairs promptly have proved very difficult to sustain. But the desirable alternative of Village Level Operation and Maintenance. is only feasible if the pump design allows for it.

Initially, the VLOM concept was applied to the hardware, the aim being to develop pumps specifically designed to be:

* Easily maintained by a villager caretaker, requiring minimal skills and few tools;

* Manufactured in-country, primarily to ensure the availability of spare parts;

* Robust and Reliable under field conditions ;and

* Cost Effective.

When the Project started, pumps meeting these needs for lifts of more than 7 meters were not readily available on the market, and their development had to be motivated. Recognizing that central maintenance cannot be dispensed with overnight, the Project has also encouraged manufacturers to improve the durability of existing pumps, to lengthen the interval between repairs.

The VLOM principles were well received. Manufacturers quickly responded to reliability problems identified in laboratory and field testing, and worked to develop pumps which can be more easily repaired by handpump caretakers or local mechanics. At the same time, planners and promoters of handpump schemes began to pass on responsibilities for maintenance to the pump users, selecting pumps accordingly and introducing training courses for pump caretakers and area mechanics. As project experience has grown, and donors and implementing agencies have experimented with better ways to design projects, alternative maintenance systems have been assessed, and it has become clear that different models work best in different circumstances. This has led to an extension of the VLOM concept into software, or organizational matters

A common feature of successful handpump projects is the emphasis on village level management of maintenance, reducing the dependence on central government support of essential functions. In the extended VLOM concept, where M means Management of maintenance, these elements have been added:

* Community choice of when to service pumps;

* Community choice of who will service pumps; and

* Direct payment to repairers by the community.

Figure 5: The VLOM concept (Arlosoroff et al,1987).

2.4 Performance and management of maintenance

For a good understanding of VLOM, it is essential to make a distinction in two factors:

1. The organizational level on which maintenance is performed (centralized, regional or local level).
2. The level on which maintenance is managed (agency managed or community managed).

We can categorize maintenance according to these two factors. Before explaining this with a few examples, I want to make some marginal notes.

✓ The difference between the mentioned regional and central level may be distinct (e.g. in the three tier system), but may also be non-existent (e.g. in projects which are limited to the regional level). As according to users, both the regional and centralized level are external; from this point of view they may be joined.

✓ The level on which maintenance is managed may be vague in the case of regional maintenance. Area mechanics might work on request of communities (i.e. if communities are unable to repair breakdowns) and on request of agencies (i.e. regular inspection of hand-pumps), or might have commercial enterprises exploiting maintenance: in the last case maintenance of community handpumps would probably be community managed, although the mechanic would of course be managing his own affairs.

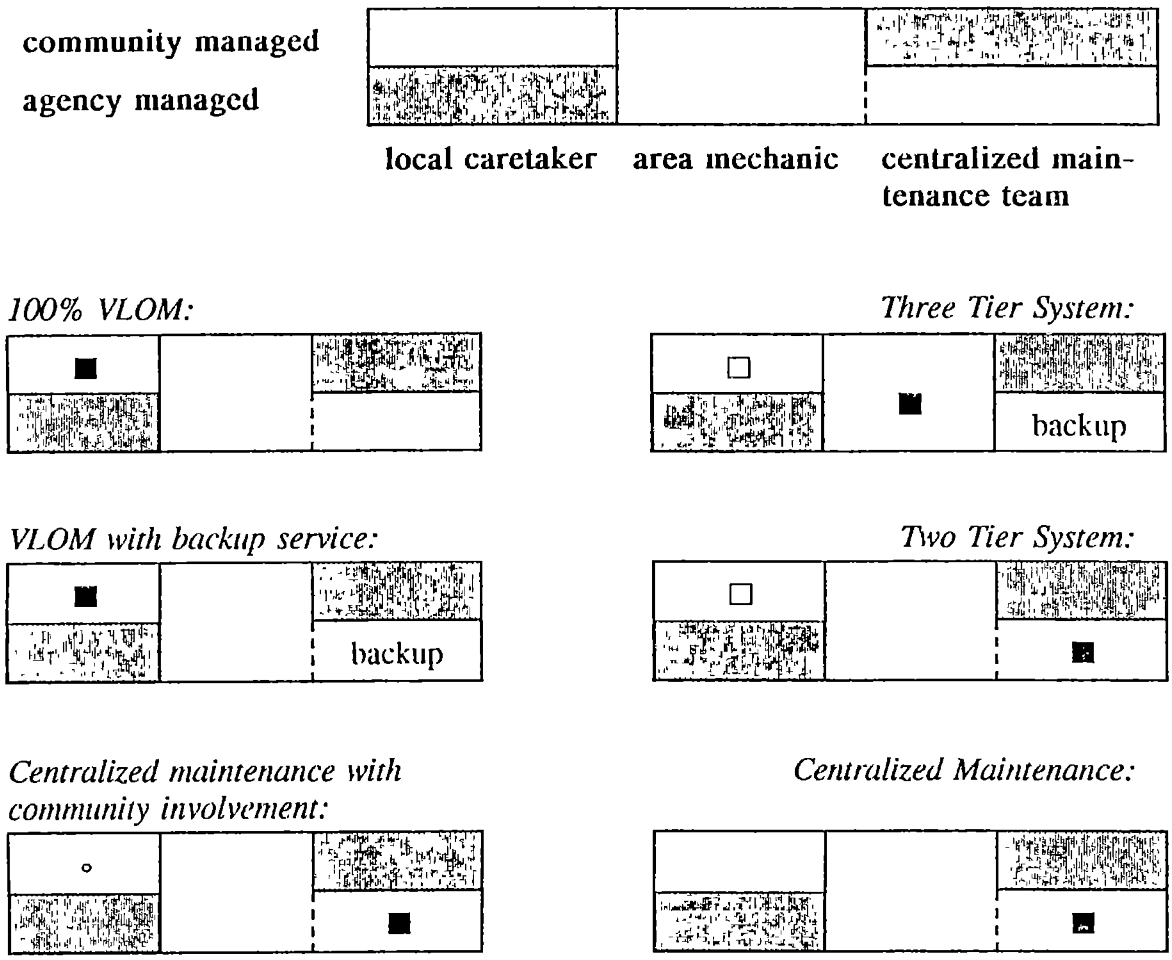
✓ Communities are *always* the first ones that identify maintenance needs and should consequently take the initiative to get handpumps repaired.

✓ In VLOM or tiered systems central maintenance teams may provide for backup service; 100% VLOM theoretically does not make use of such backup service; maintenance is performed and managed on the local level.

In Figure 6 this simple maintenance model is illustrated. Examples are given of some well-known maintenance systems. In practise every maintenance system has its own characteristics, depending on factors such as the organisation, remoteness, infrastructure, the community and persons/organisations involved. It is important to realize that such differences occur; that rural water supply settings are not uniform, and that blue print approaches towards maintenance are therefore improper. Blue print approaches come to economizing on the sustainability of supplies, as they cannot deal with the local conditions adequately (van Dusseldorp,1990).

Although the essence of VLOM has been stressed in the Project, no suitable VLOM maintenance systems have been developed recently: leaving the planners and implementors with the only statement that VLOM is (VLOM handpumps are) important. Morgan recognizes this shortcoming when he states that rather nut-and-bolt issues have been researched than maintenance systems developed (Morgan,1989(1)).

Figure 6: A categorisation of maintenance systems. In every maintenance system each executor might have own tasks, and a division between community managed and agency managed maintenance tasks might exist.



■ : main tasks in maintenance;
□ : tasks in maintenance limited to simple repairs and preventive maintenance;
∘ : only minor tasks in maintenance (e.g. limited preventive maintenance).

2.5 The present situation

Maintenance problems have not been solved until now. It is even to be questioned whether maintenance problems will ever be solved. Of course there have been improvements. In the past years several handpumps have been developed which have been found to be suitable for VLOM to considerable extent, although this is of course not a guarantee that such pumps are absolutely perfect. But even if handpumps (the hardware) are entirely suitable for VLOM, this does still not guarantee any sustainable operation and maintenance, as long as other aspects of VLOM (e.g. education, training, participation; the software) are not considered (Falkenmark,1982; Kigingi Abubakary,1984).

Both software and hardware need attention, to effect sustainable supplies. In the next chapters I will discuss both software and hardware aspects, which are important to effect sustainable VLOM-systems.

3 THE SOFTWARE

3.1 Policy

Planning and implementation takes place within the context, created by the policy concerning rural water supplies. Policy makers, being both the governmental agencies and NGOs, have therefore considerable influence on the kinds and tendencies of projects. An obvious example may be the existing water supply in India as compared to the supply in other developing countries. The extent to which water supplies have been improved, is clearly the result of the national policy on rural water supply. The attitude of policy makers is obviously of decisive importance. VLOM might need the recognition of its importance by policy makers, on all levels.

The attitude of governments (and policy makers in general) has very much been influenced by the declaration of the IDWSSD. Much countries, not having a clearly defined policy concerning rural water supply, set up such a policy after the declaration (Bron,1985). Which means that huge amounts of money are generally made available for *new* water supplies, and the attention given to maintenance remains minimal. In fact the IDWSSD-goals stimulated a new construction bias. Policy makers often seem to be in favour of promoting new, high tech- supplies; which does not only correspond to the IDWSSD goals, but also adds to their status: "..*in 1992 we installed 80 handpumps, which supply clean drinking water to 40.000 of the rural poor..*".

There is a need for the establishment of institutional and legal bases for maintenance. But this requires long term commitment to implement it as planned, stressing maintenance as a priority activity (Bastemeyer1 ,1985; Hofkes,1983). In policies the importance of VLOM, but also of maintenance in general, needs to be put forwards. In practise this would mean, for example, that agreements made between governments and NGOs about huge numbers of pumps to be installed every year, should be abolished or adapted, and that more money should be made available for maintenance of rural water supplies. More time should be allowed for the software in projects.

3.2. Planning and implementation

During the planning and implementation phase of rural water supply projects the fundament will be laid for future operation and maintenance. By means of a flexible planning, design and implementation, sustainable rural water supplies should be set up. At least the basic cause and effects of maintenance problems lie within the system of planning and implementation (Bron,1985; Fouzdar,1984).

A basic problem is the fact that planners are generally not accountable for project performance. This is frequently mentioned as an obstacle towards more realistic and appropriate project preparation (Bron,1985).

Rural drinking water supplies should contribute to the national development (Bron,1985). In fact rural water supply projects open up possibilities for further development -or close this possibilities in the case of failure! The integration of rural water supply projects with other developments, such as other PHC activities, might have mutual advantages. This might even be essential to have any long term impacts on health and enhance VLOM. Effecting VLOM, necessitating community development, might be viewed as an investment.

It might provide the basis for future developments (Donaldson,1988; Evans,1992; Falkenmark,1982; Wahadan,1990).

The first decision that should be made, preceding to intervention, is whether to improve something or not (van Wijk,1987). Due to various reasons it might be better to improve nothing. For instance, if no way can be found to provide for the maintenance of already existing handpump installations, it would probably be better to postpone major new handpump installation projects until more attention has been given to the rehabilitation and maintenance of existing handpump water supplies (Hofkes,1982). Past interventions that failed, or traditional water supply systems which felt short in maintenance, might be a guide to identify possibilities and limitations of maintenance systems. The same conditions for which systems failed in the past, might still exist; and these might be of equal importance for new interventions (Wahadan,1990; Bron,1985). Wahadan mentions a case in Sudan, in which water yards felt into disrepair repeatedly. The longstanding constraint leading to this situation appeared to be a lack of financial resources for operation and maintenance. While investigating for an improved water supply, the only thing which appeared to be changed was the economic situation: it worsened. Implementing a new water supply, needing the same (amount of) economic resources, would therefore be fruitless. (Bron,1985; Falkenmark,-1982).

Supplies have basically to reach the level at which they have to work -the level of the community- to be sustainable. For centralized maintenance systems not very much attention has to be given to the software; at least not to let the maintenance function well. Maintenance remains in control of some external agency; community education, motivation and participation are of minor importance; in theory communities have nothing to do with maintenance at all. The opposite is true considering VLOM. Bringing about VLOM systems necessitates that sufficient attention is given to this software. The higher the level of institutional inputs, the more likely it will be that the community adopt an attitude of dependency, and rely on others, for even the most simple maintenance tasks, on the long run. To prevent this from happening, communities have to be in a position to participate from the planning onwards; *Rural water supply projects have to be people oriented projects. A process approach towards rural water supply projects is much more appropriate than a project approach* (Cleaver,1991; van Dusseldorp,1990; Evans,1992; Fouzdar,1984; Hofkes,1983).

By some authors it has been advised to start with pilot projects only. Improved water supplies, implemented with a change over the maintenance system, might become a severe obstruction to further development (Wierema,1987;Hofkes,1983). For instance, when a rural water supply is set up with a centralized maintenance team, it might be extremely difficult, if not impossible, to shift to VLOM afterwards; the same is matter of fact considering rural water supply systems for which the government has been responsible for the maintenance costs initially, but where a shift to community responsibility has to be made afterwards.

3.3 Timing

Paying attention to the software means that time is needed. Enough time has to be taken for the development of projects themselves; the setting up of strategies; the procurement of pumps and spare parts; the establishment of a spare parts distribution network; and the training and education of personnel and users for their role in maintenance. This might

take years. Hofkes even argues that, when starting from a zero base, it might take as long as five to ten years before a country is able to absorb a massive handpump programme (Hofkes,1983). Account should be taken of the communities' time expenditure during planning and implementation. Activities in which the community members should participate, should be tuned to their daily pursuits. The need for taking enough time is once again highlighted by Birgit Madsen. "*Remember that to bring about change in attitudes and practise is a very slow process, particularly when it is accompanied by a demand for labour. The users must be allowed to plan the time that they need to give to the project*" (Madsen,-1990).

3.4 Monitoring and evaluation

"*We need to know what maintenance solutions work, when, and why. A good monitoring system and periodic evaluations with active involvement of the communities will make it possible to demonstrate the efficiency and effectivity of programmes, and at the same time enable managing staff and communities themselves to improve on the system*" (van Wijk,1987). With these sentences van Wijk and Visscher finish their report upon 'handpump projects: avoiding neglect'. They in fact indicate a basic need for monitoring and evaluation programmes, suitable for VLOM. 100% VLOM system require a full awareness and performance of monitoring and evaluation at village level.

Monitoring and evaluation should focus on issues related to sustainability, such as: quality of the constructed waterpoints, their usage, performance, maintenance, health awareness in the communities, the level of community participation in decision making, and the results of training of local people; the whole water supply system should, at all levels, be evaluated, to identify possible weak points and to verify whether applied methods and systems are adequate (Schoolkate,1991). The kind of monitoring and evaluation activities depends on the maintenance system largely. It will be clear that data have to be gathered from all levels involved. In many cases an awakening will be needed, of those having responsibility for data recording and collection, of the importance of monitoring and evaluation.

The community members using the supply are the first link in the collection of data. Whether they will report themselves or will be interviewed, it will be mostly through their experiences that information about the performance of handpumps is collected. Most of the time no personnel of agencies, or intermediaries, will be locally present. In these cases it is up to the users which factors considering monitoring and evaluation, are recognized, transmitted or written down. It is therefore of extreme importance that (some) community members are made aware of monitoring and evaluation. This in turn requires an awareness and commitment of personnel during implementation. If not enough attention is paid to these issues, monitoring and evaluation are doomed to fail; probably resulting in neglected supplies.

Failure of monitoring and evaluation systems embezzle the failure of projects, in which the hardware only received attention. This is possibly strongest present in those projects which have been intended to be VLOM. Unfortunately this cannot be proved.. data is lacking. The superficiality of most publications, only mentioning the success of the programme qualitatively; the lack of quantitative data on handpump performance and VLOM: and publications of some authors such as Besselink, might prove this. (Besselink,1990;-Besselink,1992; Hofkes,1983).

3.5 Preventive maintenance

Preventive maintenance is a basic strategy in the VLOM-concept to keep the reliability of handpumps as high as possible. But it is often a new aspect of maintenance in developing countries, and it might therefore be difficult to effect it in practise. This kind of maintenance should take place during operational times; at moments when usually nobody has a scant suspicion that maintenance might be needed. As for the same reason why -for instance- motor oil of cars may not be changed, preventive maintenance might not be performed by agency personel or community members, unless they are made aware of the importance and are actually willing to preform it. The same is true considering the recording of maintenance data: when maintenance is performed, this will be done because something has been out of order; and not to remember it over lengths of time and for the sake of recording it. Besides, 'the repair has only been a small one'... It may be very difficult to change such attitudes, because they are often inherent to the culture (Besselink,1992; Hofkes,1983; Srivastava,1991; Wierema,1987).

3.6 Recurrent costs
3.6.1 Maintenance costs

There are four reasons why agencies might not make sufficient money available for maintenance:

1) Due to the new construction bias;
2) Due to a lack of financial means;
3) Due to an attitude that agencies, when confronted with the decay of any supply, stage a new request, rather than pay for maintenance (Wierema,1987);
4) Due to a conviction that the instalment of VLOM-handpumps releases the agency from every responsibility for maintenance.

Whatever might be the actual reasons, it is a mentioned fact that -with an increasing number of handpumps-, agencies will not be able to continue financing maintenance all alone. Communities will have to carry this burden; at least partly. Hofkes makes a division in three financing methods: the one in which the government pays (1), in which the government subsides (2), and finally the one in which the community pays all the costs (3) (Hofkes,-1983)[2]. In 100% VLOM systems the communities theoretically pay all maintenance costs. Such payment is preferable, because communities are not dependent on external parties for financing in this way (Falkenmark,1982).

It is remarkable that only very few data exist on actual maintenance costs. This is related to the problem such as exists with the recording of maintenance. Therefore it is extremely difficult to indicate factors influencing the maintenance costs, or even roughly assessing maintenance costs which will have to be made in order to keep handpumps in operating condition. The few data which exist on this subject often come forward from huge projects; for instance the average maintenance costs needed to keep an India Mark II

[2] Of course NGOs might also pay or subside maintenance costs, in stead of governments. Whether governmental or non-governmental agencies pay or subside, depends largely on the national policies.

operational (US$ 35 per year), became available as a result of a huge project supported by UNICEF in India.

There have been made rough estimations of maintenance costs of handpumps by several authors. Maintenance costs depend on many factors, such as the pump density, pump type, well depth, numbers of users per pump, the kind of maintenance system, remoteness... World-wide estimations of maintenance costs, mostly leaving out all factors, are therefore rather blue-print, and often vague. Therefore it is not surprisingly that estimations vary considerable. Some examples:

- Falkenmark: yearly maintenance costs are 40-50% of the costs of the pump itself;
- Hofkes: yearly maintenance costs are 6-25% of the costs of the pump itself;
- Wierema: lifetime maintenance costs equal the initial costs of the installation;

Maintenance costs can be expressed as costs *per unit*, such as above mentioned costs, or as costs *per capita*. Hofkes mentions a range in costs of US$ 0.30 to US$ 2.50 per capita per year, based on a 100 persons per well. He also mentions that the maintenance costs to be paid by the users should not be extremely higher than the already existing costs for traditional water supply, plus the amount they want to pay additionally for the improved supply (Hofkes,1983).

Users should both have the ability to pay these costs(1), and the willingness to pay (2). The willingness to pay for a supply is more important to assess than the ability to pay. It reflects the value which the users place on their water sources. If users can pay more, but do not want to, the ability is of no value at all.

The willingness to pay is determined by various factors:

✓ The availability of other (traditional) water sources in the vicinity (Morgan(1));
✓ The extent to which members of neighbouring communities have to pay for their supplies (Wood,1989).
✓ The satisfaction of the users with the service level of handpumps, as compared to other supplies (Schoolkate,1991);
✓ The extent to which users consider clean water to be important for their health;
✓ Promises, made by governments or agencies, to pay maintenance costs;
✓ The extent to which the users consider the supply to be a gift, for which they do not have to pay ('the Santa Claus syndrome'[3]).

If users appear to be unable, or not willing to pay for maintenance of handpumps, the chance that VLOM would succeed, would be minimal. In fact the same is true considering the users' willingness to perform maintenance. Community attitudes have therefore to be known by implementing agencies.

Even when communities are willing to pay for maintenance, actual fund raising might still be problematic. VLOM requires collective contributions, which might be hampered by

---

[3] The 'Santa Claus syndrome' is a sort of indifference and passivity of users concerning careful treatment and maintenance (Wierema,1987). When a supply has been offered free, why being responsible for something paid for by another? To prevent such an attitude from happening, it is important to make clear that supplies are not a gift limited in time, but require continuous support from local resources. Local contributions to the supply in initial stages (e.g. manpower, the delivery of materials, but also financial) have found to be very important for this reason (Schotanus,pers.com).

for instance negative experience with collective actions or free-riders[4]. Ideally appropriate fünd-raising mechanisms should be set-up preceding the installation of handpumps. Although this is largely community business, intervening agencies might have a supportive role in it.

3.6.2 Replacement costs

VLOM is believed to add to the sustainability of supplies; but how far reaches this sustainability? Many agencies and authors seem to assume that handpumps have the eternal life. But in reality handpumps, and even dug- or drilled wells, have to be replaced after sooner or later. A lifetime of 10 years should be considered as a maximum for handpumps; drilled wells should generally be written off after 25 years of usage (Schoolkate,1991; Arlosoroff et all,1987). However, such records are rather theoretical, and are not based on field data.

Replacement of handpumps may be necessary if repair would be more costly than buying a new pump, when obtaining spare parts would become an insoluble problem or because of an overall failing performance (Besselink,1992). Replacement of handpumps however might take place gradually, i.e. replacing (almost) all handpump components with time.

Some authors argue that most communities will not be able to pay replacement costs of handpumps in the near future (Besselink,1992;Hofkes,1983). Besselink states that most projects do not succeed in realizing a sustainable pump system in communities; such systems only serve temporarily: a few years (Besselink,1992). If this is the case such development might be like a candy which will be consumed sooner or later, leaving the consumer with nothing than a deficiency and maybe some toothache. Solely from the health point of view, it would be better to stay away and do nothing than to implement a temporarily system. *The maintenance issue of handpumps is of minor importance to sustainability if we do not consider future replacements of the supplies. All interventions will be worthless in the end, all our efforts and money will be useless, if we forget about this issue.*

Whether agencies will have to be responsible for replacement costs -which is not to be expected in most cases-, or communities will have to carry this burden. From the contributions of community members savings might be made for the payment of replacements; but in most cases it will even be difficult enough to cover general maintenance costs (Schoolkate,-1991). Even if communities would have the ability and willingness to pay for the replacement costs; and if money for replacement has been gathered some time; it would not have to be expected that communities would automatically go on with the gathering. Replacement funds are immense amounts of money -in the eyes of community members. Only a small part of the replacement costs would already be an amount of money of which individual members could only dream. If a considerable amount of money would be gathered, a felt need of still raising more money might be totally absent. Dekker observed such a situation in Dosso, Niger (Dekker,pers.com; 1993). Next to this point, savings for replacement costs are sensitive to devaluation of currency, and to corruption. It might be difficult to manage replacement funds, and to make the money profitable before investing it in a new handpump; credit systems or

---

[4] Free-riders being persons, that do use the supply but in one way or another do not contribute to it.(Wierema,1987; v. Dusseldorp,1990)

investment facilities might be absent. Communities might be unwilling to replace old handpumps. Other investments might have priority; or community members might rather like to wait for a new -free- handpump installation by some agency (Besselink,1990).

Problems such as might occur with the savings for replacement of handpumps, might theoretically also happen with the general savings for maintenance.

Next to realizing the need for replacement of handpumps and wells, it has be realized that also the functions of caretakers, mechanics and managers have to be taken over by other community members with time. *Projects have to be reproduceable on the local level, with local resources only*. Until now, this has only been an ideal.

3.7 The covered geographical area

"*To keep a single pump in operating condition is not so difficult if it is lavished with care and qualified maintenance personnel.. in contrast it is extremely difficult to keep a large number of pumps in operating condition, particularly when these pumps are widely distributed in difficult terrain*, in a country with a low level of development and having relatively few people with technical training and management experience" (Hofkes,1983). In most cases, VLOM will require a backup service, for those maintenance tasks which the communities cannot handle themselves. The bigger the geographical area, in which centralized teams operate, the bigger the problem to provide for such a service adequately; transportation costs increase -and will become too high to visit a single handpump to provide for backup service; which means an attack on the reliability of supplies (Wahadan,1990).

A related factor is the handpump density. If the handpump density decreases, problems with providing backup service will generally increase. Next to this, a handpump density too low obstructs possibilities for regional maintenance by private enterprises, and regional stocking of spare parts. Whether there will be transportation difficulties, or the number of pumps repaired by one mechanic will be too low to make a living (Hofkes,1983).

3.8 The settlement pattern

The settlement pattern of the population may be of decisive importance considering the possibility for effecting VLOM. If people live in communities, relatively close to each other, this will not be too limiting. But what in the case of dispersed settlement, or nomadic population? In this case we even have to wonder whether handpumps would be appropriate. Who will be responsible for maintenance or payment?

Nomads can impossibly make use of one handpump only; their lifestyle requires series of water supplies. Handpumps might only be an option if they would be maintenance free, or if they would be maintained by governments or NGOs, without the users being responsible for the costs. Another option might be private (exploited) wells.

In the case of dispersed settlement the number of people fetching water from one single well would be limited, and consequently recurrent costs would be high; too high for community payment of maintenance.

It may be obvious that the settlement pattern might make any extent of VLOM practically impossible. Therefore it is not surprisingly that some authors write about settlement programmes. In such programmes it would be the objective to induce people to settle in larger communities. Although it is not in the scope of this report to deal with these

programmes, it is my conviction that such inducements cannot be justified, at least not for the sake of clean water supply only. Alternatives on handpumps should be sought in these cases. Dug wells, whether open or protected, would probably be the most affordable solution. OXFAM Ethiopia did consider settlement problems. This organisation came to the conclusion that the installation of handpumps would be an unsuitable solution for the provision of clean water to the nomadic population in the Hararge and Ogaden region, due to the nomadic style of living, and the reacheability of the well sites. Therefore they provided for (hand-dug) wells without handpumps in these regions (OXFAM:Bazezew, pers.com).

3.9. Spare parts distribution

The success of VLOM depends entirely on the availability of spares at community level. The lack of spare parts at the local level has proven to be one of the most common problems of rural water supply, even with centralized maintenance (Arlosoroff,1987; Baumann,1990; Donaldson,1988; van Wijk,1987)

Unfortunately the lack of spare parts is a general problem in many developing countries. The procurement of spare parts is often extremely difficult. Not only if they have to be procured from other countries, but also if they are produced in country. The problem has to do with national legislation and rules about importation, a general lack on foreign currency in foreign countries, the in-country infrastructure, and the overall attitude towards maintenance (Besselink,1992; Schotanus, pers.com; Afewerk Bairu, pers.com). In many cases problems exist considering the organization of spare parts distribution systems. Sometimes an implementing project or a department authority has the task to distribute spare parts; but often the earnings vanish –and the stock is consequently not replenished. Spare part distribution is often unprofessional or even non-existent. When spares are available in-country, they still have to find their ways to the user communities. Near capital towns or prime cities this will generally not be too problematic, but in remote areas the infrastructure might severely delay delivery of spares (Besselink,1992). Regional or local stocking of spares therefore offers the best perspective. The times for which mechanics or caretakers would have to wait for spare parts would be lowered by regional or local stocking; particularly in VLOM systems. Besides, it would be ridiculous if a local caretaker in a VLOM-system would not have access to spare parts because of centralized stocking -under the implementing agencies' control for instance.

Local manufacturing of handpump components and standardization might have considerable effect on the availability of spare parts. The distribution and stocking of spare parts would be facilitated by such measures (Arlosorof,1987; Hofkes,1983; Wahadan,1990; Schoolkate,1991).

Schoolkate mentions three options for local stocking of spare parts: selling spares in local private stores, selling them in special governmental stores or cooperative village stores, and distributing them by the agency (Schoolkate,1991). Advantages and disadvantages of these options are given in Figure 7. Distribution by agencies should not be considered as a permanent option, because of the lasting dependency. The attitude of agencies towards independent distribution systems however might not be not too enthusiastic; it would imply the handing over of extra responsibilities to others, and might therefore be unwanted.

	local private stores	governmental or cooperative stores	distribution by the agency
characteristics	commercial stores in larger villages or district centres which already are distributing agricultural implements, and are visited for that reason.	stores of the same kind as under 'local private stores', but more oriented to selling agricultural implements, and originating from governmental or cooperative initiatives	distribution of spare part by the implementing agency; the most suitable option when community payment for spare parts has not been introduced.
advantages	✓ frequently visited stores ✓ continuity of supply is reasonably assured	✓advantages as under 'local private stores'	✓ people with technical knowledge of handpumps are involved
disadvantages	✓ spares may be expensive ✓ continuity may be less assured ✓ fewer problems with the selling of handpump spare parts	✓ selling of spares may not be very lucrative; difficulty with stocking many different spare parts while selling relatively few of them	✓ generally poor performance ✓ hight costs ✓ continuity badly assured

Figure 7: Options for organizing spare parts procurement and distribution (Schoolkate,1991).

General problems, with which local or regional commercial distributors have to live, are a limited turnover, a low profit, difficulties to find suppliers of spare parts, long delivery times, paying in advance, and import restrictions. Manufacturers of spare parts might have their own problems, such as the delivery of spare parts, years after installation of the pump, and small margins due to limited numbers (Besselink,1992).

A related advantage of VLOM is its smaller dependence on transport; transport facilities might also suffer from a lack of spare parts. If such facilities are broken down, maintenance of regional or centralized maintenance systems might seriously be obstructed. Hofkes mentions a case in Ghana, in which motorcycles, used by handpump mechanics for transportation, were out of order for almost 50% of the time, due to breakdowns and shortage of spare parts (Hofkes,1983).

3.10 Actors

3.10.1 The interface

Contrary to more centralized maintenance systems, VLOM requires a large transfer of knowledge to the local level. Which means, that it requires a larger *interaction* between agency personnel and community members.

Agencies might listen to the wishes of local communities in some extent, but might still want to put planning and implementation in a way *they* like it, because, implicitly, they belief to know best. But VLOM requires a change in attitude towards the communities; a deeper investigation of the communities' wishes and other local factors; and time.

The *partnership approach* offers some perspective on this subject. Agency personnel

and community members should be equal partners according to this approach. Communities, and especially women, should be included in the decision making process; there should be a consultation *between* the intervening agencies and the communities. All parties should be adequately informed about the project and its implications (Schoolkate,1991). The *interface* theory describes such an interaction. This theory describes interventions as 'meetings' of two different worlds, in which both parties learn about each other's objectives, attitudes, perceptions and wishes. If an understanding thereof does not become reality, this leads to ignorance, and partial or total failure of projects (Long,1989(1))[5].

Effecting VLOM requires that communities are viewed as actual partners in planning and implementation; in decision making. Their perception and wishes are of decisive influence on the success or failure of projects in general, and especially of VLOM. They should know what VLOM actually brings about. VLOM can only succeed if communities have actually chosen for it, and are not obliged to participate.

3.10.2 Agency personnel

It might be clear to the reader that VLOM is essential for sustainable rural water supplies. About the opposite might be true for the personnel of intervening agencies. Do they want VLOM? Personnel of agencies, with technical backgrounds, might rather like to keep it the way it always has been- rather than going to occupy themselves with the sociocultural *softy* stuff. Besides this, technical skilled personnel active in (maintenance of) rural water supply projects might fear to loose their job by a shift to VLOM: a fear which is mostly without reason, as the need for backup service remains. Such a reserved attitude towards VLOM might make adequate rewarding of personnel advantageous (Arlosoroff et al,1987; Wahadan,1990; Munguti,1989; Cleaver,1991). For the same reason personnel must adequately be trained and informed about the essence of VLOM, education and community participation. (Schoolkate,1991; Madsen,1990). In selecting personnel, it might be better to select project managers with management skills and experience than having technicians managing projects (Bron,1985). For the same reason it might be better in involve skilled community workers in community participation and education, than involving technicians.

It has been one of the conclusions of a report by the Inspection of the Dutch Development Agency that one of the main causes of partial or complete failure of drinking water supply projects has been the gap between the necessary and the actual input of personnel. The personnel corps has been too small and there have been minimal capacities for good project preparation and monitoring of target group projects (Wierema,1987).

3.10.3 Community members

Water supply projects can never be planned or implemented without a change of community attitudes, relations, or without community reactions. We can compare communities with balanced ecosystems. Whenever one single change would be brought about, this

[5] The interface theory, and other aspects of development sociology such as about knowledge systems are of great value for an understanding of rural development programmes. It would be too much to discuss them extensively in this report. Interesting publications on these subjects are described in the list of references: Long,1989(1); Long,1989(2); Long,1992.

might have large effects. As long as effects are positive in the eyes of all the users (which is often presumed rather than investigated) nothing is wrong.. but negative effects will unfortunately be present in most cases. For instance, women, traditionally obtaining some money by water selling, might loose their income; people too poor to participate because of the recurrent costs might suffer from a worsening situation (Wierema,1987). Negative effects may lead to conflicts within the community, and even to a complete failure of projects.

Besselink, mentions a number of problems which might occur in VLOM systems as a result of local conditions:

✓ the people responsible might not be taken seriously, might not be obeyed, or might not be trusted. community assistance is based on voluntariness; apart from moral pressure, hardly any sanctions exist.

✓ the villagers might not assist responsible persons, but rather oppose and impute them.

✓ target groups in communities might be inaccessible because of balances of power in the village (e.g. exclusion of women).

✓ problems might exist within the community, such as between families and quarters, castes, ethnics, religious groups, or because of external (political) influences.

✓ VLOM might not offer any real profit, but might cause only more problems (e.g. excessive costs, frequent breakdowns, difficulties to get the pumps repaired). In the eyes of community members only disadvantages might come along with VLOM. Villagers might rather have a 'wait and see' attitude than putting their own shoulders to the wheel (Besselink,1992).

It is very important that community members feel the need for an improved supply, from the health point of view (van Wijk,1987). In fact a recognition of the importance of clean drinking water, or a request for a handpump, is even not enough; this might be because of the community status too. Community members have to *feel the need*; clean drinking water has to be of the highest priority. These are prerequisites of VLOM, as handpumps will not be maintained, and certainly no money will be spent on it, if users do not feel the actual need for clean water, and do not realize why a handpump should be kept in operating condition in the presence of maybe several traditional supplies. This might require the creation of an *awareness* of the importance of clean water, sanitation and hygiene (Schoolkate,1991).

In VLOM-systems community members are responsible for the supply themselves. Such *responsibility should not only be given on paper; members should actually feel responsible themselves*. In practise it appeared that communities should have a sense of wnership, to feel responsible for maintenance. Participation from initial stages onward might be essential, to create such a sense of ownership.

Besselink talks about *sensitization*: the creation of an awareness of the importance of clean water and the communities involvement. (Health) education, training and motivation may therefore be essential (Besselink,1992).

Schoolkate identifies three ways through which an awareness might be stimulated. Economical and social benefits of improved water supplies might be emphasized; health awareness programmes might be started; improved water supplies might be integrated with other developmental programmes. (Schoolkate,1991).

3.11 Local factors

Wierema researched the impact of local factors on the maintenance of rural water supplies. This author identifies sociocultural, economical, organizational and technical factors, some of which I already mentioned. A summary of them is given in Figure 8.

3.12 Enforcing local traditions and technology

For community members handpumps are in most cases something new; they are not traditional, but from outside: they are *white*, not *black*[6]. They originally do not belong to their traditional 'black' society. Therefore handpumps, will not accepted automatically. Ideally 'white' handpumps will be incorporated in the 'black' system; but this might require an enforcement of local traditions and technology.

Local traditions and technology considering rural water supply exist in every community. Ideally VLOM enforces them: For instance enforcing traditional fund raising mechanisms, traditional knowledge in maintenance, knowledge about health (Wahadan,1990). Traditional values might become a barrier to development, if projects require a change to modern -external- values. This again is particularly true considering VLOM. For instance, if women have to perform maintenance tasks which are traditionally performed by men. VLOM has to be a communities' maintenance system, as according to their view, enforcing their own means. Community development may cross existing barriers to VLOM. But implementing agencies have to be aware not to impose their meaning on communities. For instance, they should at least wonder whether it would be allowed to go for changes in the traditional relation between men and women, if none of the community members ever complained about that relation.

During an international workshop on the role of communities in the management of improved water supplies, held in the Hague in november 1992, some examples have been given about local knowledge and traditional management of water supplies. Although these do not consider handpumps only, they might be an indication that the enforcement of such traditional knowledge and management is possible. Figure 9 displays some of the examples.

3.13 Community management

"*Rarely does the village maintenance system fail due to the mechanic's inability to perform the repair. When problems are encountered these have more to do with managerial, administrative and organizational problems...*" (Wahadan,1990).

Community management has been found to be the basic issue of VLOM (Arlosoroff,-1987). It should bring about an improving reliability, sustainability and an increasing cost-effectiveness (Evans,1992). Unfortunately community management of maintenance is also one of the most critical aspects of VLOM. Community management of -modern, 'white', maybe

---

[6] I want to use the terms 'black' and 'white' for 'traditional' respectively 'non-traditional'. It has nothing to do with any racial division. The only justification to use these terms lies within the fact that they are used in some African contexts by local community members themselves.

SOCIOCULTURAL FACTORS
✓ the need for a supply and the priority of that need; ✓ the matter of access and distribution, or the way access to the different supplies has traditionally been distributed; ✓ how to take this traditional distribution of access into consideration when designing and constructing new supplies; ✓ knowledge and information; ✓ traditional rights; ✓ local participation in the decision making process and in management of the supplies; ✓ power relations in the community; ✓ gearing the supply to the composition of specific user groups; ✓ the role of cultural rules and social quality criteria concerning the supply, its use, its maintenance and costs;
ORGANIZATIONAL FACTORS
✓ the lack of emphasis placed on the organizational prerequisites to sustainability of drinking water supplies so far, and some different organizational options available; ✓ the limits to government agencies and their interventions; ✓ users' maintenance and backup systems; ✓ the possibility to base a modern operation and maintenance organization on a traditional structure; ✓ the organization of user groups; ✓ the concept of accountability; ✓ local capability; ✓ the infrastructure of an area; ✓ training and education;
ECONOMIC FACTORS
✓ financing problems; ✓ the ability and willingness to contribute and therefore the degree of economic incorporation of the community; ✓ the possibility of forming surpluses from capital generating activities, and thus the availability of rewards in order to enable different forms of management; ✓ local experience with pooling and/or other forms of contribution; ✓ the differentiation of economic interests; ✓ the possible role of corruption;
TECHNICAL FACTORS
✓ former solutions to the problem; ✓ the standardization dilemma; ✓ the demand of technological appropriateness of a supply and the criteria to decide on that appropriateness; ✓ the different aspects of such appropriateness; ✓ user problems and the adaption of engineering concepts to locally acceptable standards; ✓ the local technology as a starting point of project design; ✓ the familiarity of the users with preventive maintenance;

Figure 8: Local factors of importance considering VLOM (Wierema,1987).

COUNTRY	PEOPLE	OBJECTIVE AND METHODS
Ethiopia	Borana	Water Source Protection: Silt is cleaned out from ponds, and thorn fences built around them to protect the slopes
		Water Point Management: Well users form a council, and delegate authority over the well to a clan elder under the direct supervision of a council of elders. The elder in charge is responsible for organizing use and maintenance of the well.
		Ownership and Access to Wells: Permanent wells are owned by clans, but access to them does not necessarily depend on clan membership but on negotiations based on manpower contributions to digging and maintenance.
Mali	Tuareg	Water Treatment: Small holes are dug in ponds and filled with soil from termite mounds to precipitate impurities.
	Bambana	Ownership of Wells: Deep wells dug through rock, or which need expensive materials to construct them, are usually owned by the village or ward. Shallow hand-dug wells are usually owned by the individual household.

Figure 9: Local knowledge and traditional management in some African examples (Narayan,1992).

alien- water supplies requires an organizational level, participation and motivation of the communities which cannot be put aside as being insignificant. It is impossible to assume that community management is appropriate in all cases, or that it can be easily be effected. Practical training programmes to develop (basic) skills as bookkeeping, budgeting, community surveys, setting up action plans or technical skills to maintain handpumps, need to be part of all handpump programmes (van Wijk,1987; Madsen,1990). Unless community members already possess such skills. But practise has learned that it may even be needed to learn community members to write (Dekker,pers.com).

Community development will therefore be prerequisite to the effecting of community management of maintenance systems in most cases. The diagram in Figure 10 illustrates community management of maintenance and its relation to the (actual) community level and community development. If community management of maintenance would not be possible as according to present conditions, the it might be rejected, or communities might be developed in such a way, that community management of maintenance would become possible. Rejection of community management might come to effecting other management systems (e.g. a division in responsibility between agencies and communities, or agency management), or to total rejection of water supply projects. In cases in which sustainability can not be guaranteed other than by community management, total rejection may be the best alternative.

Effecting technical skills, necessary for VLOM, requires the technical training and

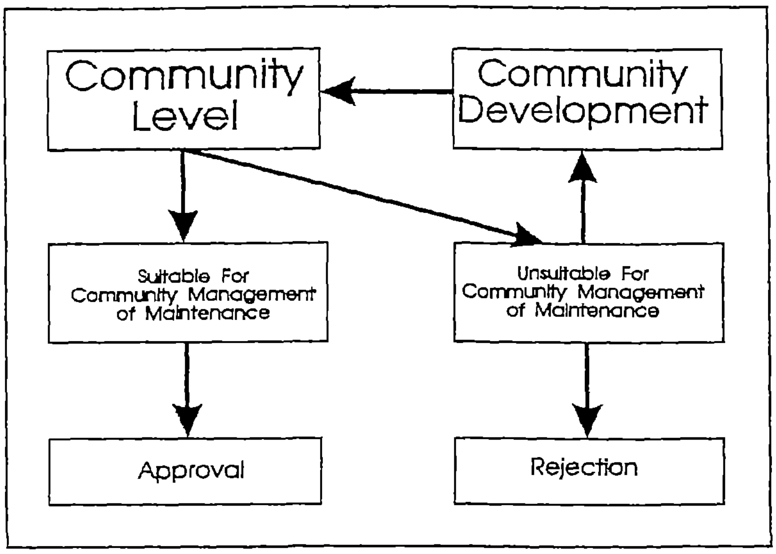


Figure 10: Approval or rejection of community managed maintenance systems, on base of the community level and community development.

education of community members. In fact this is also a kind of community development, and the diagram in Figure 10 may also be used for this reason. But, as this paragraph might have made obvious, effecting technical skills appears to be less problematic.

The management of maintenance takes place within a local organization. Such a organization may exist of a water committee and a certain number of caretakers and/or mechanics. Wierema identifies seven factors which are of importance considering VLOM, and are related to the local organization. These are:

1) Preliminary research should be done into the degree of organization existing in communities and the possibility for making links with existing processes in view of the future users.
2) The selection of an organizational structure for operation and maintenance of rural water supplies should be done as early as possible.
3) It should be assessed whether such an organization is present, and if yes, how it functions.
4) There should be looked for local counterparts to take over the project when completed.
5) Depending on the technology chosen and the knowledge that is locally available, demands for timely training and schooling for those responsible for the supply will have to be met.
6) It is recommended to cooperate with the already existing schooling opportunities, because such a link offers the best guarantees for sustainability.
7) It is recommended to arrive at such a structure that those in charge of the maintenance of the supply are accountable to the (other) users of that supply (Wierema,1987).

The existence of a dynamic and motivated local leader and a high degree of congruity of interest within the communities has found to be very important (Cleaver,1991; Shamala Devi,1988; Suciplo,1992). Even after maintenance has been organized (i.e. when a village water committee has been set up), traditional leaders continue to play a prominent role in water supply and management of operation and maintenance. This is hardly surprising in view of their customary role in the management of communal resources, such as often

present. It does however suggest that policy recommendations for membership of committees may actually miss the point where the dynamics of community level activities are concerned. The same might be true with the women's roles in community water supply. In the Dosso project, Niger, it appeared that, although women were the official responsible persons for organizational activities, their men carried out their function in practise (Dekker,pers.com). Cleaver identifies the same problems in Zimbabwe (Cleaver,1991).

3.14 Community participation

"*There seems little doubt that the encouragement of community participation pays off in many ways. Installations which are put in place with active community support are much more likely to survive than those in which the villagers have neither been consulted nor involved*" (Morgan,1989(1)).

In fact the term 'participation' means both the participation of community members in initial stages of projects, and the partial or entire participation of community members in maintenance (VLOM). This might be rather confusing, certainly because most authors do not distinguish between the two kinds of participation.

Community participation in initial stages has often been considered to be the key to a sense-of-ownership of the communities. But it should not be a kind of formula: participation effects a sense of ownership; a sense of ownership effects successful VLOM. Participation may even work out contrary, as White points out: beneficiaries may feel they have done their share by contributing to the construction and agencies should consequently ensure the proper functioning of the facility (Wierema,1987; White,1981).

Participation ensures that the knowledge of community members about their physical and social environment is fully used. It enables projects to take into account the varying needs and capacities for contribution of different users/ user groups. By participating in initial stages, communities might learn the terms of their participation in maintenance; what they can expect from agencies, and vise versa (van Wijk,1987). Participation adds to the general development of communities, and opens doors to sustainable VLOM.

The exact reasons why agencies stimulate community participation, may be less noble than at first sight. Munguti mentions that the participation of community members often intends a cost-saving delivery of labour only. On paper it might seem great, but actually there may be questions as to what compromises community participation, and subsequently what technologies communities can ably manage and maintain at their own level, and with their own means. Community participation should put the community *first*; a reversal of the belief that project staff knows everything best (Munguti,1989). But probably community participation is often stimulated for the own well-being of the project staff and their agency. Isn't it true that community participation often takes place during the construction phase of projects, and in maintenance like 'maintaining a fence' and 'keeping a pump site clean?'. In which activities, requiring semi-skilled personnel, do communities participate? White distinguishes three dimensions in participation, being *involvement in decision making*(1), *implementation*(2), *and sharing in the benefits*(3) (White,1981). In practise so-called 'community participation' often remains with some meagre contributions in implementation. It is no wonder that this 'sense of ownership', and motivation have been lacking in so many cases..

Next to an unwillingness to effect participation, agencies may not have the necessary organizational skills and resources to do so. There may also be constraints in the immediate

project surroundings (Bron,1985).

Putting the communities first implies that communities decide about participation (Wahadan,1990). If community members would not be willing to participate, participation would rather imply rejection than creating a sense of ownership of the supply.

As a result of the sociocultural structure present in communities, there may be major limitations to community participation (Bala,1990).

For these reasons it has to be questioned to which extent communities can possibly participate. An analysis of participation by White is very enlightening. He distinguishes ten categories of community participation, in an order of increasing participation-level:

1. Consultation; with community representatives.
   with other community members.
2. Financial contribution of communities towards construction.
3. 'self-help' activities of some community members; contributions (labour,material) of members, especially during construction, to reduce costs. Largest input remains with implementing agencies.
4. Conform category 3; with the only difference that whole communities collectively contribute.
5. Training of one or a few community members to perform specialized tasks.
6. Collective mass action of community members, directly aimed at obtaining general benefit. Inputs by agencies are rather small.
7. Collective commitment to change personal behaviour, and collective social pressure for the realization of such changes.
8. Self-reliance in the sense of the autonomous generation, within the community, of ideas and movements for the improvement of living conditions, as opposed to stimulation by outside agents. Recourse to external agencies for help with implementation might be present.
9. Self-reliance in the sense of using only the efforts of the community members themselves and not appealing to outsiders for help.
10. Self reliance in the sense of using local materials and manpower, rather than collecting funds internally in order to purchase goods and services from outside; including increasing local capacities with this kind of self-reliance as a goal (White,1981; Bron,1985).

100% VLOM of handpumps would at least require a participation-level as described in the 9th category. And it has to be questioned whether such participation level can be reached in all cases, or with short-term community development. The required participation of communities in operating and maintenance may seriously hamper any attempt to effect VLOM.

4 THE HARDWARE
4.1 Introduction

If the software side would be well-considered, creating maximum possibilities for VLOM, but the handpump used would need four well educated professionals for even the simplest replacements of spare parts....

There are three technical factors (the hardware), which are of particular importance considering rural water supply with handpumps: the aquifer, the well, and the handpump. Mainly the handpump is of importance for VLOM; it is that part of the technology where rural communities will be dealing with in practise. Although the aquifer and the well characteristics will certainly have influence on the overall performance of handpumps, they do not influence the possibility for VLOM systems very much. A broad study of these subjects has therefore not been within the scope of this report.

4.2 Handpumps

Until a handpump needs maintenance, its design does not influence the possibilities for VLOM that much. But when maintenance is needed -be it preventive maintenance or repair-, appropriate handpump design becomes a prerequisite for VLOM.

The UNDP/WB Handpumps Project introduced guidelines for design of handpumps: the so called *design-criteria*. For a good understanding it is necessary to realize that the VLOM design criteria are twofold:

1) shortcomings of the handpumps should be solved, to raise their reliability;
2) handpumps should be made suitable for VLOM.

So-called *VLOM-handpumps* are handpumps which fulfil these criteria. In order to investigate a handpump's worthiness to receive the VLOM-status an extensive (endurance and abuse) testing programme has been started by the Consumer Research Laboratory (CRL). An outline of this testing programme is given in Appendix 1. This testing programme gained so much authority that manufacturers scramble to obtain a good rating for their pumps (Arlosoroff,1987; Bron,1985; Reynolds,1992).

In fact there's neither rhyme nor reason in the term 'VLOM-handpump'. A handpump is only than a VLOM-handpump when it is -in fact- maintained on the local level. Handpumps may be suitable for VLOM, but that does not say anything about the way in which they will be maintained in practise. Unfortunately the term 'VLOM-handpump' suggests that the fact whether a handpump can be maintained on the local level or not, merely depends on the pumptype chosen. But whether VLOM is possible or not depends on the software too.

All handpumps have shortcomings (the ideal handpump is maintenance free, consequently has the eternal life, and is still to be designed). For the time being not all the shortcomings can be maintained in VLOM systems; which means that still no 100% VLOM handpumps exist (Hofkes,1983). When exactly a handpump is considered to be suitable for VLOM is rather vague. The India Mark III, the successor of the well known India Mark II, is considered to be a VLOM-handpump. Official documentations mention that this handpump approaches the VLOM concept, because more than 90% of the repairs can be carried out on the local level (Gov. of India,1990; Mudgal,pers.com; Reynolds,1992).

But even if a handpump would be suitable for 100% VLOM on one location, would it be as suitable on a second location? Let me give this example: the India Mark III, as tested

by the CRL, uses a galvanized iron (GI) rising main. In India, where the pump has been designed, GI does not cause problems that much. pH-rates are generally moderate to high in India. In contradiction, if we transport that same pump to Africa, and plant it somewhere, problems might be tremendous, because of low pH values (4-4.5). In such cases the India Mark III should not be considered to have VLOM capacities *by far*. The rising main might be rotten in a few years (Besselink,pers.com/1992; Bonnier,pers.com). Hence *VLOM-guidelines are general guidelines. The exact VLOM-qualities of handpumps have to be assessed according to the local conditions.*

Before village level maintenance becomes evident, handpumps have to be accepted. It might be that the kind of operating mechanism of a handpump effects the social unacceptability of that pump. Maybe the best example would be the Vergnet footpump, which is often said to be unacceptable to (pregnant) women because of the exertion required in operation (Besselink,1992). This may be true, but probably most authors mentioning this factor have heard it said, rather than investigated it in practise (Grey,1987). Besides, also the social acceptability differs from place to place, and any foot-operated pump might very well be socially accepted in other cases.

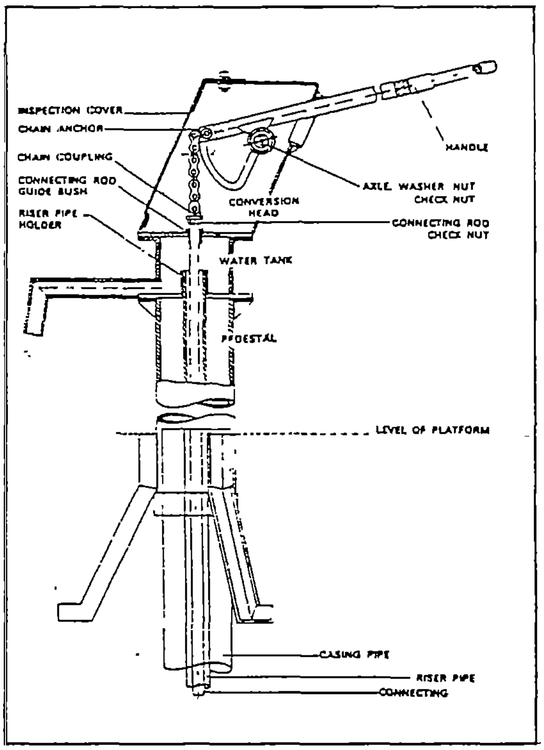
Acceptation of handpumps would theoretically be effected optimally by enforcing local designs of handpumps. In my opinion this is mostly a theoretical dream. There are only few examples of handpumps in developing countries in which one could speak about local design. The best example might be the (traditional) Zimbabwian Bush pump. This pump has first been designed in 1933, in the rural areas of Zimbabwe. Many models, dating back to the mid 30s are still operating today, while newer versions of the pump appear to be inferior to the original design. The pump is claimed to have the capacity to lift water from depths of 100 meters and its design ingeniously incorporates local materials (Cleaver,1991; Morgan,1989 (2)).

There exist several types of handpumps. Handpumps are most commonly categorized according to the depth range for which they are suitable. This depth range is by far the most important factor concerning the suitability of handpumps. We can make a distinction in the next categories:

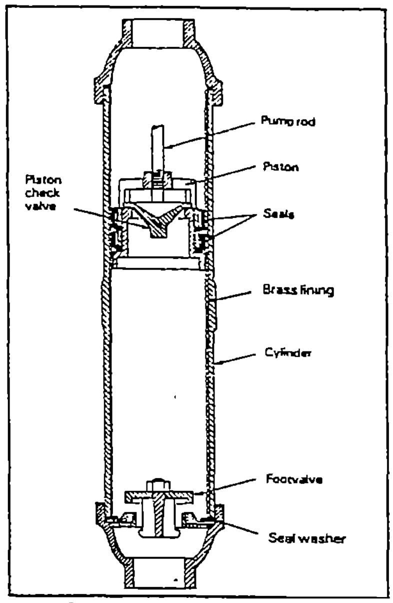
- *low lift handpumps*	suitable for lifts up to ±	12 meters;
- *intermediate lift handpumps*	suitable for lifts up to	25 meters;
- *high lift (deepwell) handpumps*	suitable for lifts over	25 meters.

An outline of the five most common types of handpumps is given in Figure 11. *Piston pumps*, such as the deepwell reciprocating handpump and the direct action handpump, are the most common pumptypes. I will especially deal with these pumps. In Figure 12 an outline of such piston pumps is given.

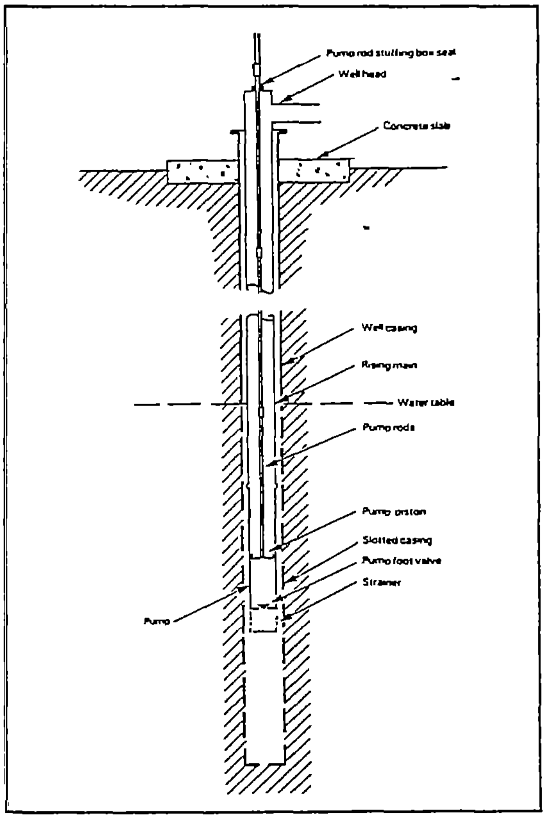
In the seventies, when overall maintenance problems with handpumps had been identified, the first attempt to overcome this problem had been the '*golden pump philosophy*': designing for high quality handpumps, almost without maintenance needs. These expensive handpumps would be better, and on the long run cheaper, than simple, maintenance requiring handpumps; maintenance of which practise had proven that it was not performed. In the Netherlands this has first led to the development of the Shinyanga pump, followed by the



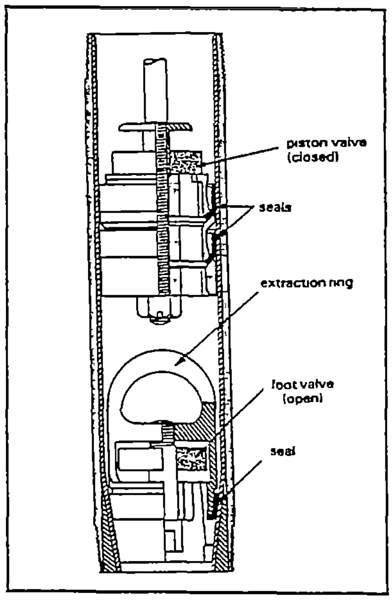
▸ *Outline of the pumphead of a India MarkII handpump. This is a deepwell reciprocating handpump.*



▾ *The outline of a standard cylinder of a piston pump (Fraenkel,1986).*



▾ *Cross-section through a borewell supplied with the below-ground components of a piston pump(Fraenkel,1986).*



▾ *An Open Top Cylinder of a piston pump; with extractable piston and footvalve (Fraenkel,1986).*

Figure 12: An outline of piston pumps.

LOW LIFT		INTERMEDIATE AND HIGH LIFT		
SUCTION PUMPS	DIRECT ACTION PUMPS	DEEPWELL RECIPROCATING PUMPS	DIAPHRAGM PUMPS	PROGRESSING CAVITY PUMPS
Suction Pumps can lift water from aquifers up to 7 meters below the surface, by creating a partial vacuum in the suction pipe. All moving parts are above ground.	Direct Action Pumps can lift water up to 12 meters. They have a down-the hole cylinder, which plunger is driven directly by the operator, without mechanical advantage achieved through a lever or flywheel.	Deepwell reciprocating pumps differ from direct action pumps in that sense, that they do have a mechanical advantage through a lever or flywheel. This feature enables the pump to lift water from deeper aquifers	With diaphragm pumps the operator's applied force is turned into a pumping action through alternate stretching and relaxing of a membrane, which is filled with a fluid in a closed system. The alternating volume of the membrane is used to lift water	Progressing Cavity Pumps lift water through a rotary motion. A helical rotor turns in a fixed rubber stator and progressively pushes the water upwards.
EGEO-1	*Kangaroo*	*India Mark II*	*Vergnet*	*Mono*

Figure 11: Different pumptypes (Arlosoroff,1987).

Kangaroo and SWN pumps (Bron,1985). However; such pumps appear to be vulnerable to breakdowns, and when broken down, they are even harder to repair (Wierema,1987; Bourbe,pers.com). The claimed 'maintenance-free' status of handpumps is therefore a fallacy; and might only be used as a claim to justify high priced handpumps (Grey,1987; Hofkes,-1983). If handpumps are vulnerable to breakdown, be it not too frequently, this is no problem as long as they remain maintainable: this is the key-item of maintenance, particularly of VLOM. *Handpumps should be maintainable.* It should be possible to solve those breakdowns, which occur most frequently (which have to do with wearing parts such as bearings or valves), rather quickly. When the 'zero-maintenance' status is assumed in the design, maintenance-free handpumps may fail on this behalf.

4.3 Reliability and maintainability

Reliability and maintainability are the two most important factors which have to be brought about in design. There are three factors through which the reliability of handpumps can be expressed:

Between

Mean Time Before Failure = *the average period a pump is in operating*
(MTBF) **condition, being the mean operating time between two breakdowns.**

Mean Down Time (MDT) = **the average period a pump is out of service after it breaks down.**

Availability = **the probability that equipment will be in operating condition on any one day.**

(Oostendorp,1988;Arlosoroff et al,1987)

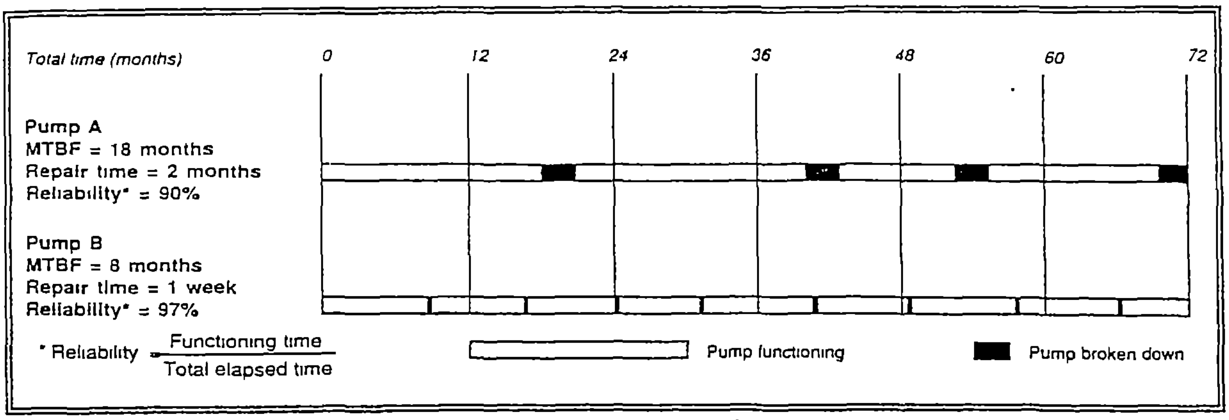


Figure 13: The reliability of handpumps as determined in two examples (Arlosoroff,1987).

The availability is the best indicator of the extent to which communities can *rely* upon handpumps (the *reliability* of handpumps, in its broadest sense). This availability-is determined by both MTBF and DT, and should be as high as possible; ideally 100%. Reliability in its original -technical- sense is determined by the MTBF. In the MTBF, the maintainability of handpumps remains out of attention. This maintainability of handpumps finds its reflection in the DT of handpumps. This might be illustrated by the example in Figure 13, as derived from the UNDP/WB.

VLOM has mostly to do with this maintainability. However, because of the lower DTs of VLOM systems (the mechanic and caretaker are locally present continuously), lower MTBFs are allowed while still receiving good or adequate ratings. The -technical- reliability of VLOM-handpumps is therefore allowed to be lower than in more centralized maintenance systems. Reliability ratings of the UNDP/WB handpumps testing are the following:

centralized maintenance	: good rating is MTBF[7] ≥ 24 months
VLOM	: good rating if MTBF ≥ 6 months

These ratings might give the wrong idea that the design of VLOM pumps is less demanding. This is not the case. Those maintenance tasks, which can be performed on local level, might be needed more frequently; i.e. preventive maintenance or the replacement of wearing parts. But maintenance tasks requiring external intervention should theoretically never be necessary. These might for instance be the lifting or re-installation of rising mains, replacement of filter packs, or repairs on other non-wearing parts. Hence VLOM requires specific design. Certain breakdowns, which would be repairable in centralized maintenance systems, should never occur in VLOM systems, because of the communities' inability to solve them.

[7] At a certain discharge. The UNDP/WB made a division in three discharge categories, being one of $1.5m^3d^{-1}$, the second of $4.0m^3d^{-1}$, and the third of $8.0m^3d^{-1}$ (Arlosoroff,1987; Grey,1987).

4.4 Maintainability

If handpumps would be unmaintainable, this would imply that it would be impossible to overcome breakdowns. Unmaintainable handpumps would operate once, and it would not be possible to repair them once broken down, independently of the maintenance system or the willingness to have it repaired. Obviously the maintainability of handpumps is important.

Maintainability is not an issue on itself; it depends on the skills of the persons that perform maintenance. If handpump repair takes place on the local level (VLOM), handpumps have to be designed in such a way that local people can perform maintenance, making use of their local skills, resources and maybe some knowledge derived from supplementary training.

The issue of maintainability is twofold. On the one side handpumps have to be designed is such a way that breakdowns are repairable on the local level. For this reason maintenance may not require skills too high. On the other hand handpumps have to allow for preventive maintenance; which implies that the time to get access to handpump components has to be limited. If it would take hours to check the condition of valves, preventive maintenance would *never* be carried out, and nothing would be done until breakdown.

For these reasons wearing parts of VLOM-handpumps have to be accessible. Next to this, the right spare parts and tools have to be available. Although such availability has primarily nothing to do with pump design, two design features may influence the availability of spare parts. These are the standardization of components, and the possibility to manufacture spares on the local level (Arlosoroff,1987; Donaldson,1988).

4.4.1 Accessibility

Accessibility of handpump components in the pumphead will generally not be too difficult to bring about in design. But as soon as belowground components have to be maintained, the accessibility becomes rather complicated (Donaldson,1988). For this reason the design guidelines have especially aimed at the accessibility of below ground components.

One VLOM guideline states the following: "*Handpumps should be designed in such a way that scheduled replacement of all wearing parts can be carried out by a village caretaker... There should be no requirement for heavy lifting gear to remove pistons or footvalves and no need for any vehicle (other than perhaps a bicycle, public bus, or transport animal) to carry tools or pump components*". Another guideline stresses that the replacement of any wearing part should not take more than two hours. (Arlosoroff,1987).

In conventional designs, piston seals, footvalves, and other downhole components, can only be maintained by removing the entire rising main, including rod, cylinder, strainer and water. A GI riser and rod together may have an average weight of 5 kg per metre: which means that the weight of a 40 meter installation would already be over 200 kg! The dismantling of such belowground components requires high skilled personnel involvement, the strength of at least 4 adults, heavy material such as sturdy tripods, and lots of time. In VLOM systems this would be impossible. Apart from this there would be a high danger of damaging riser/rod material during frequent lifting and re-installation, which would lead to more frequent breakdown and corrosion.

Below ground components of handpumps are the ones which are most frequently causing breakdowns. 25% of all replacement parts appear to be seals. All together the below ground components account for 75% of the replacements! (see Figure 14) (Arlosoroff,1987).

The basic means to facilitate accessibility has been to create the possibility to lift pistons and valves *through* the riser main; thus creating the possibility to replace downhole wearing parts without lifting the entire rising main. This has resulted in the development of the so-called *Open Top Cylinder* (OTC). The development of OTCs has been the largest (technological) step towards VLOM. OTC designs entail a number of modifications in design. The largest modification is the use of larger diameter rising mains (and sometimes cylinders with smaller diameters). Which makes OTC designs more expensive than conventional designs. In the case of the India Mark III, the increase of 40% in capital costs, as compared to the original India Mark II, is largely the result of the usage of large diameter (GI) risers. This percentage would still have been much higher when Stainless Steel (SS) risers would have been used (Arlosoroff,1987; gov. of India,1990; Reynolds,-1992).

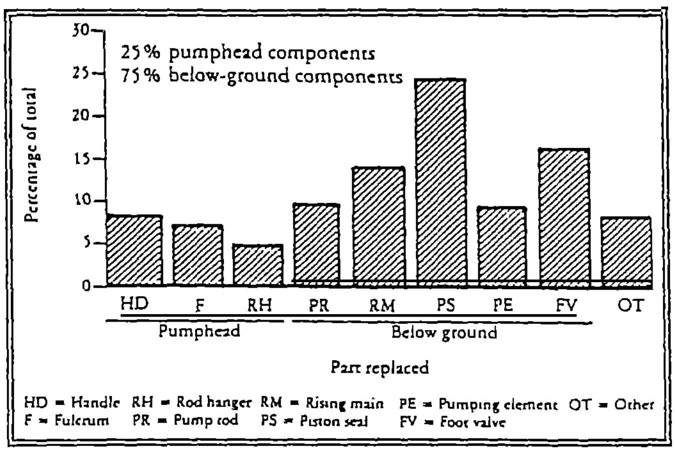


Figure 14: Repairs by part type (Arlosoroff,1987).

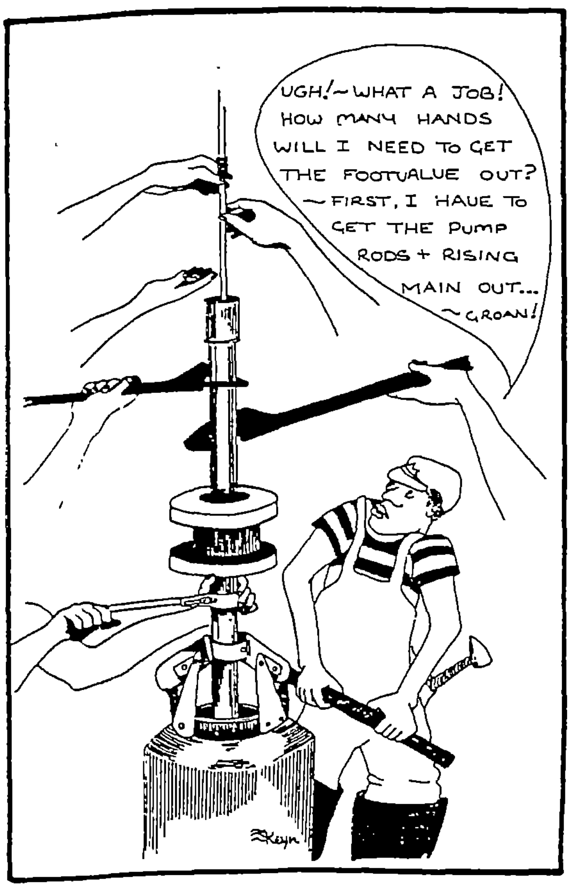
Next to facilitating the extraction of pistons and valves, large diameter risers are

claimed to minimize the wearing of the risers such as caused by banging of the rods (gov. of India,1990). This might be true in the case when no rod centralizers are used; but it has not been proven.

Many other developments have contributed to the accessibility of below-ground components. Rods are often designed to be easy-to-(dis)connect, for instance with hook-and-eye couplings. Handpumps may require the use of one single tool only; nuts may only need to be slackened, in stead of being removed, preventing them from loss...

But whatever improvements have been made and will be made in future; fractures in risers, clogged screens, infilled wells, or dropped rising mains (i.e. problems with non-wearing parts) would still require external assistance. Such breakdowns might be prevented from happening to the largest extent, but can never be excluded entirely. The need for backup service remains, such as even becomes evident in the latest VLOM-designs. Especially if risers (or rods) are sensitive to corrosion, and water is aggressive, the need for backup service would remain present. (Arlosoroff,1987; Besselink,1990/1992; gov. of India,1990; Reynolds,1992, UNDP/WB,1987).

The use of plastics has contributed largely to the accessibility and reliability of handpump components, such as bearings and valves, and especially of risers. Although the need for lightweight risers diminishes with the incorporation of OTCs, extraction of risers in exceptional cases is facilitated, and plastic risers are corrosion resistant and often available in developing countries. Problems with plastic risers are typical extra-deepwell problems, which I will discuss in chapter five.



4.4.2 Standardization of components

Imagine a women caretaker in a small community in the middle of nowhere. She's inspecting a handpump's downhole components. No problem, she's had some training, did it more frequently; accessibility of the downhole components is excellent. Well, she discovers that the piston seals have had their longest time, and therefore decides to replace them. No problem; it's possible to snap them in place by hand. She removes the old seal, pulls the worn rubber in two parts and grabs in her small toolbox (she only needs for the one single tool and some spares) to look for the seal.. but only finds some footvalve seals and the postcard with which she *had* been intended to order piston seals two months ago...

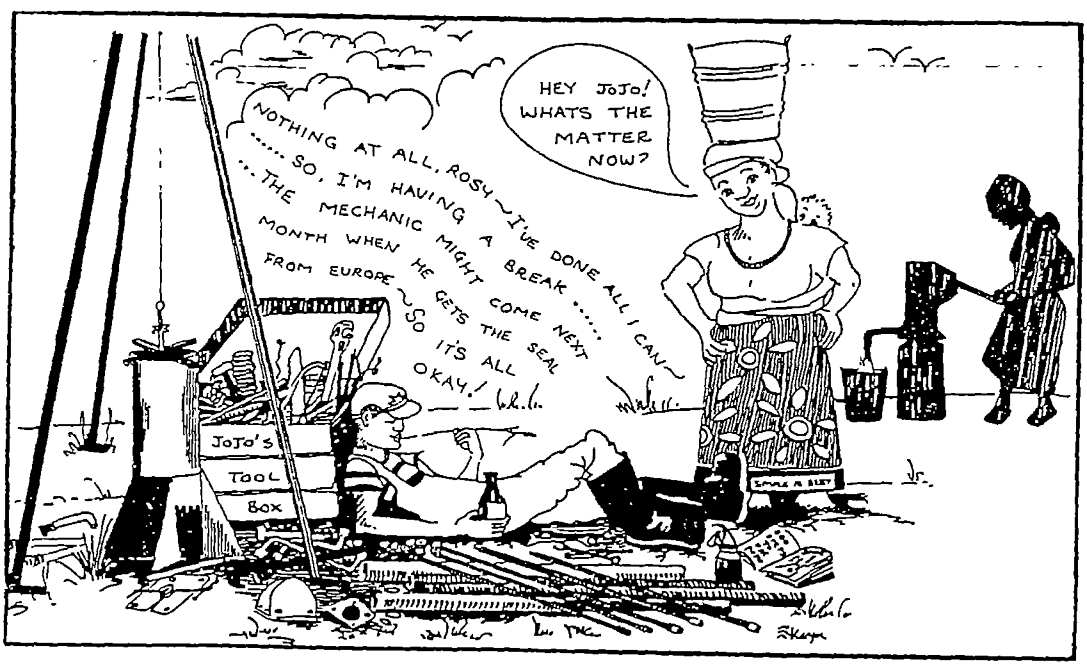
A problem raised. It may be typical to illustrate the essence of standardization of handpump components. When handpump components are interchangeable, this brings about a higher availability of spare parts. In fact the Handpumps Project only promoted the standardization on handpumps as a whole; standardization on one or a few handpump types per country or region (Arlosoroff,1987). In this sense standardization is rather an organizational matter. Standardization of handpump *components* however has also its advantages, which has not always been stressed clearly. In the Afridev concept such standardization has been put forward. Pistons and seals are identical, and one single cylinder covers the whole depth range over which the pump functions (UNDP/WB,1987).

Another often unconsidered option is the standardization on universal components in different handpumps. It would for instance be convenient if universal flanges with standard bolt centres, or standard bolt and nut sizes were used in different designs. This effects the interchangeability of handpumps and handpump components, and may therefore lead to a higher availability of handpumps. For the time being this has only been brought about in a few designs, such as the Afridev, which allows for interchangeability with the India Mark II and Maldev handpumps (Arlosoroff,1987; Reynolds,1992; UNDP/WB,1987).

4.4.3 Local manufacture

Local manufacture of handpumps and handpump components is claimed to have positive effects on the availability of handpumps, and therefore on the possibilities for VLOM. Leaving the issue of local manufacturing out of attention, I want to stress that ideally designs allow for local manufacturing; which means that handpumps can possibly be manufactured in third world countries. The Project made a division in countries with a low industrial base (1); those with a moderately developed industrial base(2); and those with a well developed industrial base(3) (Arlosoroff,1987). Practise has learned that local manufacturing is only possible in developing countries with a moderately developed industrial base at least. In many designs there will be specific components which require development in developed countries. A typical example may be the diaphragm of the Vergnet footpump. Typically the manufacturing of cylinders requires a high industrial standard.


~GROAN~ I CAN'T REMEMBER HOW TO PUT IT TOGETHER AGAIN NOW!
OH JOJO— I FEEL SO SORRY FOR YOU ~ MY PLUNGER + FOOTVALVE DON'T COME APART, SO I CAN'T EVER GET MIXED UP. SEE!—THEY ARE BOTH THE SAME!—ALL I CHANGE ARE THESE SEALS + BOBBINS!
GLUE
TOO
BOX
PLASTIC IS BEST


HEY JOJO! WHATS THE MATTER NOW?
NOTHING AT ALL, ROSY ~ I'VE DONE ALL I CAN ~ ..... SO, I'M HAVING A BREAK ....THE MECHANIC MIGHT COME NEXT MONTH WHEN HE GETS THE SEAL FROM EUROPE ~ SO IT'S ALL OKAY!
JOJO'S
TOOL
BOX

India Marke[illegible]
concept
41 43 x 42

4.5 Examples of handpumps

In order to illustrate some design features that effect maintainability on the local level, I would like to explain the India Mark III and Afridev designs; both deepwell reciprocating handpumps, that allow for VLOM to a large extent, and have been developed recently.

4.5.1 The India Mark III concept

The India Mark III is a VLOM derivate of the India Mark II. The pump can lift water from SWLs of 45m or less. The design of the handpump is illustrated in Figure 15.

The pump is claimed to be a major advance in facilitating maintenance by the users themselves. Reynolds compares the India Mark II and III, and mentions the following: *..Repairs to India Mark III pumps took just one third of the time needed to carry out similar repairs to Mark II pumps. The Mark II requires a minimum of four semiskilled workers with a mobile van and special tools to repair the below ground components. By contrast,a mechanic, carrying all the necessary tools on a motorbike, can extract the piston and footvalve of the Mark III with the assistance of the pump caretaker or another member of the user community. A mobile team is required for the relatively infrequent replacement of the rising main or cylinder body only* (Reynolds,1992). Figure 16 and 17 might illustrate this.

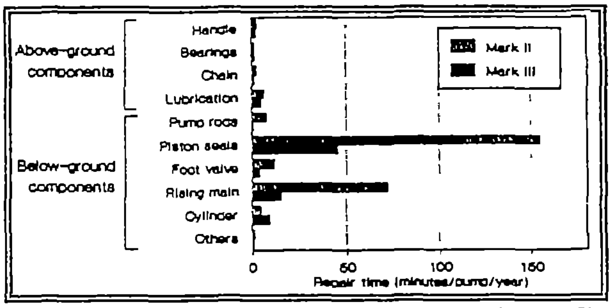


Figure 16: Active repair times of the India Mark II and -III pumps (Reynolds,1992).

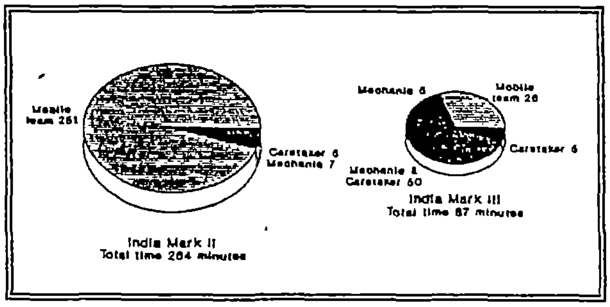


Figure 17: Maintenance regimes, India Mark II and -III pumps (Reynolds,1992).

The India Mark III encompasses an Open Top Cylinder (OTC), 2½-inch GI rising main[8] and GI rods. The piston can be extracted without removing the rising main. Overall access to the below ground components has been facilitated. Some features are:

✓ Only five simple tools required for all maintenance;
✓ Adjustable handle length;
✓ On average 50% less time needed for repair;
✓ Reduced spare part replacement frequency, and reduced annual costs (Rs 268.80 a year as against Rs 437.50 for the India Mark II);
✓ Rate of recovery required for maintenance expenses is about 50% lower;
✓ Increase in the capital costs of 40%; this increase is claimed to be offset in less than three

[8] The India Mark III has also been tested with μPVC rising main (Reynolds,1992). Early versions of the India Mark IIIs, called OTC India Mark IIs, have been installed in Sri Lanka, using μPVC rising mains and SS rods (with threaded connections) (GTZ,1988)

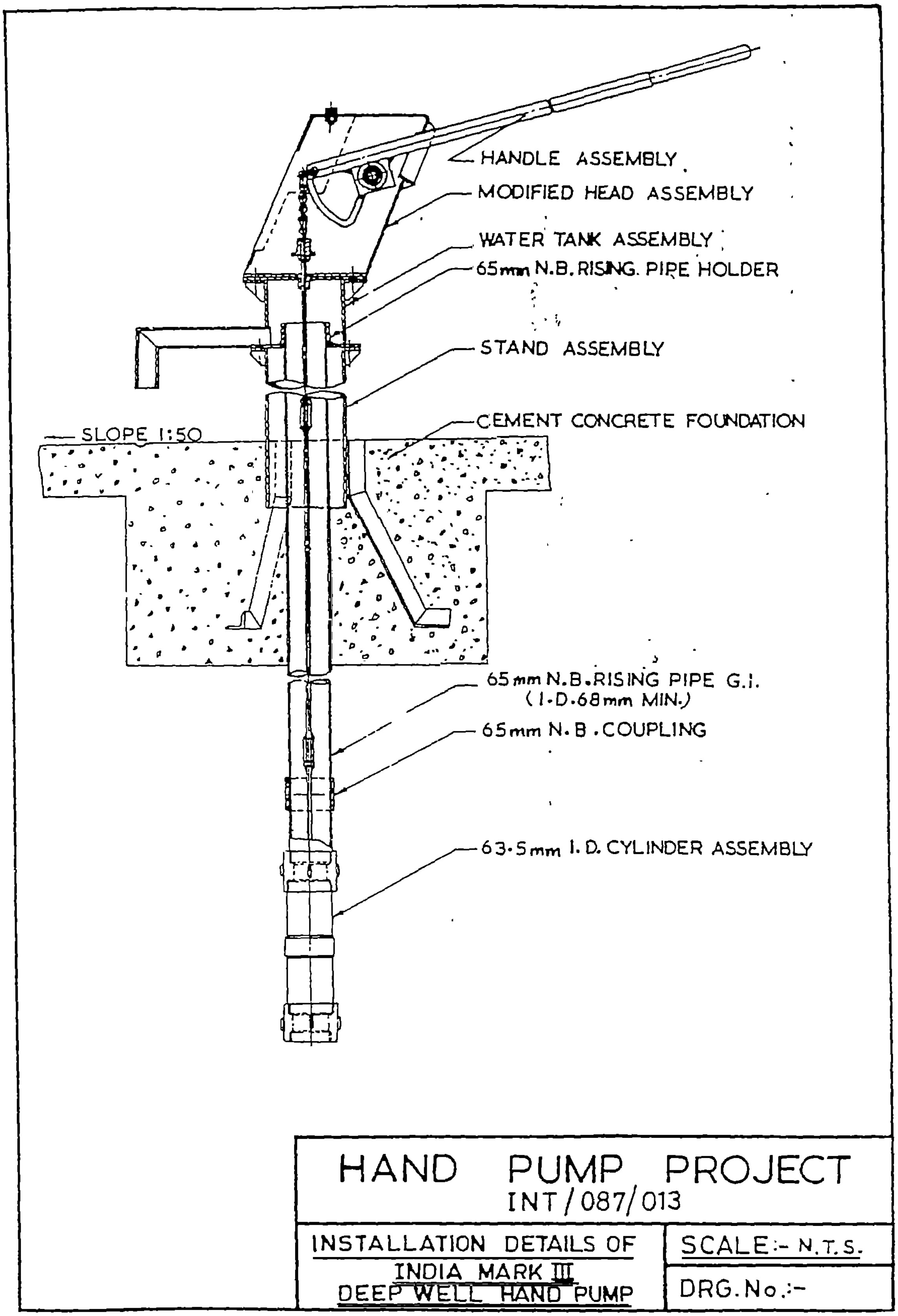


Figure 15: Installation details of the India Mark III handpump (gov.of India,1990).

years due to reduced maintenance costs;
- ✓ The area/village mechanic can carry out over 90% of the repairs with the help of the users/caretakers. Subsequently the down time is less;
- ✓ The use of a two- rather than three-piece upper valve, to eliminate failures due to disconnection of the threaded joint, and a two piece footvalve;
- ✓ Nitrile rubber seals rather than leather;
- ✓ A square rather than round bearing housing on the handle; it increases rigidity and minimizes distortion during welding, and increases the service life of the bearings;
- ✓ The modified construction obviates the need for removing the handle assembly during repair;
- ✓ Lifting of the connecting rod is easy. A mechanism to lift the valve guide when the piston is connected to the footvalve for extraction, dumping the column of water when the footvalve is raised a few millimetres;
- ✓ A deeper tank eliminates splashing of water during fast pumping;
- ✓ A reduction in overall pumpstand height reduces the banging of the handle on the bottom stop of the pumphead bracket. Next to this it brings about higher convenience for the users.

(gov.of India,1990; Müller,1990; Reynolds,1992; Srivastava,1990)

4.5.2 The Afridev concept

The Afridev has been developed in Malawi and Kenya, out of the Maldev handpump. The pump is claimed to be *the* handpump for (at least) East African countries. It has indeed been developed to function well under conditions such as exist in East Africa. The corrosion resistance of the pump might illustrate this.

From the start of its development onwards, it has been the aim to design a handpump that was very easy to maintain at village level and could be manufactured in countries where industrial resources were limited. Absolute simplicity of maintenance, and minimum quality control requirements to simplify manufacture have been the objectives. The Afridev should show that deep well handpumps *can* be maintained by village men and women, *can* be manufactured in most developing countries and *can* still be affordable and reliable. Figure 18 illustrates the design of the Afridev. Some design features are the following:

- ✓ 2½" µPVC rising main; GI or SS rods with hook/eye or other thread-less connections; SS OTC. Both plunger and footvalve can be removed through the rising main; lifting the footvalve is possible using a small fishing tool;
- ✓ Only two tools are required for all maintenance and/or repairs;
- ✓ Adjustable handle length;
- ✓ it has been designed to minimise forces, without reducing the discharge, and to minimise the number of spares, by using an uniform small diameter, long cylinder for all depths;
- ✓ The number of spares has further been minimised by using only one component for both piston and foot valve body;
- ✓ The use of plastic or rubber wearing parts only;
- ✓ Bearings exist of two part polyacetal/nylon plastic; cheap, mass production possible;
- ✓ Wearing parts are designed to service for two years, but should be replaced annually to avoid breakdowns;
- ✓ All maintenance can be performed quickly. Nuts and bolts need only to be slackened and cannot be removed, all have the same size;

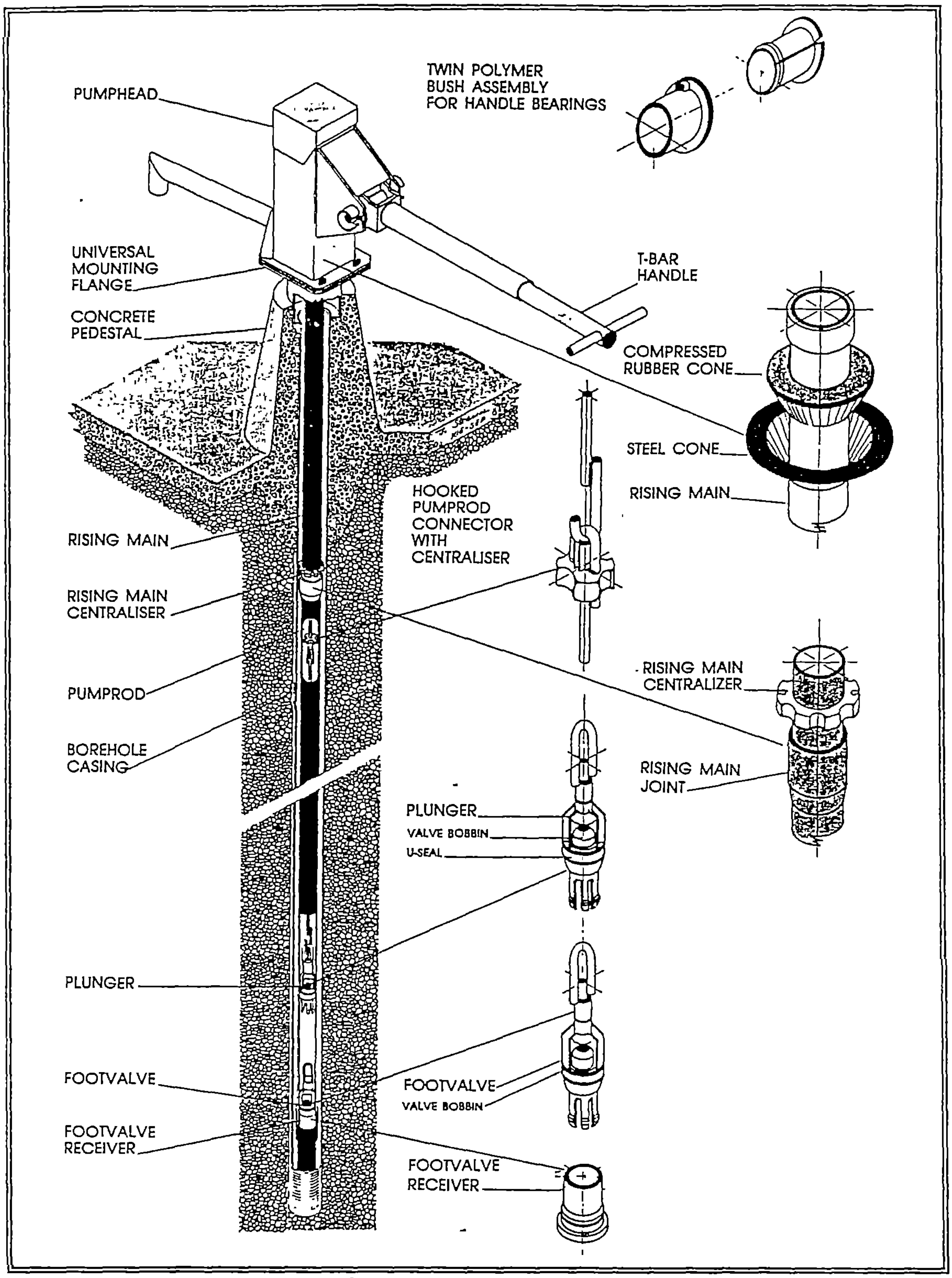


Figure 18: An outline of the Afridev design (UNDP/WB,1987).

5 VLOM: TO WHICH EXTENT?

5.1 Introduction

I discussed the VLOM-concept, and made clear that whether VLOM can be performed or not depends on both software and hardware aspects. To which extent is VLOM possible?

Although the essence of VLOM may be clear, some authors state that VLOM has no sense at all. According to Bonnier VLOM is unrealistic, because it does not look into the real problems: the negative or disinterested attitude of governments and agencies concerning maintenance, rather spending US$ 100.000 on new water supplies than using it for the upkeeping of already existing installations (Bonnier,pers.com). Such criticism is not justified; it rather criticises the issue of maintenance in general. VLOM might still be the best maintenance system, *if* attention is given to maintenance.

When pumps are rejected by the users, VLOM is completely absent; but in fact one cannot speak about water supply systems or maintenance anymore in such cases. When pumps are in use, and in that way accepted, there will always be an extent to which VLOM is performed; maintenance activities of users, in a try to keep a pump operational, or to satisfy own needs. For instance, the prolonging of the spout of handpumps, to prevent them from splashing, or to facilitate water fetching. I observed such spontaneous modifications in a community in Southern Shewa, Ethiopia.

It has often been evaluated in literature that VLOM succeeds and all maintenance is successfully performed on the local level. Let me give some examples:

"*63 Women in the district of Mirzapur, Bangladesh, were trained as voluntary pump caretakers using 21 Tara handpumps. They received 6 hours of classroom training and 2 hours of practical training. When evaluated over a 15 month period the pumps maintained by the women volunteers functioned as well as those maintained by trained pump mechanics. These findings are significant as an indication...*" (OUP,1991). The same report mentions a small increase in 'fit' pumps at inspection visits, namely 89% in stead of 86% It mentions nothing more about external intervention than 'inspection visits' -which fact indicates that some external control exists in this case. Nothing is mentioned about external interventionists putting their shoulders to the wheel; interventions which have not been made unnecessary yet, proven the fact that still 11% of the handpumps were out of order despite their VLOM-maintenance. Only a 15-month period has been considered; A short period which would certainly not be representative for a whole handpumps' lifetime. It seems like the author wants to indicate that VLOM functions as well as, or better than, other maintenance systems. But such conclusions cannot be drawn from such data.

Paqui writes: "*Malawian Women Keep the Pumps Flowing: .. Broken Down Pumps will soon be just a bad memory in Malawi. Community self-help in maintenance reduced the breakdown rate by 75% while the response time between breakdown and repair* (down time) *hardly exceeded two weeks. Handpump caretakers like Ms. Chagwera routinely tighten loose nuts and bolts on the pump, replace parts that wear out.. ..Ms Chagwera was selected to undergo a one week course at a training centre... ..„It's in the best interest of me and my family to maintain the pump", she says, „I remember too well how sick we used to get from water drawn from the polluted stream before we had the pump""* (Paqui,1989).

Such phrases are biased; it is my fear that actual constraints to VLOM are underestimated and obscured in this way. Besselink even argues that reports leave facts about external control and performance of maintenance out of attention. Actually handpumps in so-called

(100%) VLOM systems remain operational because "*once every year some 'white' people in a jeep will come along and maintain the pumps*". In such cases it is unrealistic to speak about 100% VLOM systems (Besselink,pers.com). Probably the data of such documentations are not right, incomplete, or limited in time, and therefore the conclusions of such documentations are not trustworthy. It is remarkable that hardly any articles have been published which reveal some constructive criticism on VLOM. Considering the limitations of both hardware and software such criticism has to be expected. Even the original concept mentions the need of backup services and maintenance tasks remaining to be carried out on regional or centralized level.

Although I found no evidence of it, it might be the case that all breakdowns or failures of VLOM-systems are assigned to failures in maintenance system setup or failures in handpump technology: "*problems occur due to the fact that VLOM has not been effected adequately/ to a sufficient extent*". In such a way real constraints to VLOM might never be revealed at all!

A failing recognition of the difference between maintenance and repair might trouble the conception of VLOM. *While preventive maintenance can be performed on the level seemingly easy, it may be much more difficult to effect repair.* When authors discuss VLOM, they might discuss preventive maintenance only; leaving the repair issue out of attention. This confusion can rather clearly be identified in the article written by Paqui.

Obviously there has to be a balance between those maintenance tasks performed on the local level, and those performed more centrally. *Implementing agencies have to consider the limitations of VLOM; have to maximize the extent of VLOM, but without passing the limitations such as put forward by software and hardware.*

5.2 A comparison with other maintenance systems

In the previous chapters I already indicated a number of advantages and disadvantages of VLOM as compared to other maintenance systems. Several authors did make such a comparison. In this paragraph I want to summarize the comparisons of three authors. They are an enlightening indication that VLOM has its limitations.

The maintenance systems which these authors mention have great similarity to the maintenance systems such as categorized by the UNDP/WB Handpumps Project. For the sake of completeness I will give an outline of these categories.

1.	*Community Management of Maintenance:*	*1A.*	*Village Caretaker*
		1B.	*Area Mechanic*
2.	*Central Management of Maintenance:*	*2A.*	*Central Maintenance with Community Involvement*
		2B.	*Central Maintenance*

Note the division according to the 'community management' and 'community performance' of maintenance, such as mentioned in chapter 2. Category 1A reflects 100% VLOM systems.

Elson made a comparison of maintenance systems based on this categorisation. Figure 19 views this comparison. It is very typical that Elson does not make a distinction in two 'community management' categories; which in fact means that he does not consider community management without support from area mechanics or other private enterprises.

Community Management

inspections, repairs, renovations and replacements are carried out by the members of the community or under the communities direction. Support to the community can be provided by private enterprise (spares and services) or purchased from a government agency

Advantages:	Disadvantages:
✓ fast response to problems ✓ in control of own affairs ✓ develop pride in own abilities and achievements	✓ needs motivated people with appropriate level of skill ✓ may require engineering facilities ✓ need to hold expensive stock of spares

Centrally Managed with Community Involvement

Simple routine inspections and repairs are carried out by the users, but a centralized specialist group looking after many handpumps will visit periodically for major inspections, overhauls, and repairs.

Advantages:	Disadvantages:
✓ community retains reasonable measure of control and responsibility ✓ back up for major problems beyond local resources ✓ pride in maintaining pump is developed	✓ community dependent in part on another organization ✓ delays awaiting actions of central group ✓ skilled team needs to be properly resourced to be effective ✓ expensive vehicles required

Centrally Managed

All work is carried out by a central agency

advantages:	Disadvantages:
✓ smaller stock of spares required per pump ✓ concentration of skills and resources	✓ slow response to remedy breakdowns ✓ high cost and possibly poor service ✓ routine inspections may not be carried out ✓ no involvement or commitment by the community

Figure 19: A comparison of three categories of maintenance systems (Elson,1992).

A division of UNICEF in Nigeria compared VLOM with 'community funded, private sector operated' and 'government funded and operated' systems. This division has been based on the financial aspects of maintenance, rather than on the management of the systems. The categories may be compared with respectively category 1A, 1B and 2B, such as used by the Project. They are displayed in Figure 20 (Donaldson,1988).

VLOM

Advantages:	Disadvantages:
✓ Easy integration with PHC programmes; ✓ Funds generated and used within the community; ✓ Short response time for action; ✓ User ownership ensures safety and durability of systems; ✓ Involves local governmental administrations in administration.	✓ Requires access by community to well ✓ Trained and dedicated personnel ✓ Requires high level of mobilization to promote acceptability by users ✓ Community leaders can abuse position by restricting use

Community Funded, Private Sector Operated

Advantages:	Disadvantages:
✓ No strain on the governmental budget; ✓ Quick response since operators will want to maximise profit; ✓ Quality workmanship guaranteed if payment tied to performance.	✓ Services difficult to integrate with other PHC components; ✓ Abdication of government role to provide service to justify taxation; ✓ Inability of some communities to meet the costs.

Government Funded and Operated

Advantages:	Disadvantages:
✓ Funds provided in budget; ✓ Recognition of the need for adequate maintenance by governments; ✓ Easy to integrate with other PHC interventions.	✓ Top-Bottom bureaucratic structure causes high cost external to users; ✓ long communication channel delays action at user end; ✓ Possibility of diverting funds to other purposes; ✓ Communities do not perceive themselves as owners and may abuse facilities.

Figure 20: A comparison of VLOM and non-VLOM Maintenance systems (Donalson,1988).

Besselink compared three management systems, being VLOM, 'management by commercial enterprises', and 'management by (semi-) governmental services'. The 'management of commercial enterprises' system considers community funded, private sector operated maintenance systems; in which maintenance is a kind of service communities can 'buy' for their handpumps. Such a system may be compared with system 1B. The third category may again be compared to centralized maintenance systems (2A/B). Advantages and disadvantages are displayed in Figure 21. Besselink concludes that handpumps maintained in VLOM and 'management by commercial enterprise' systems have probably the highest availability, and the lowest costs; although VLOM is not always found to be realistic (Besselink,1992).

VLOM	
Advantages: ✓ great involvement of the village in their system, there will be dedication and social control;	Disadvantages: ✓ communities have to be financially and organizationally able to manage such maintenance systems; ✓ socio-cultural factors and external influences like politics, economy and climate might make VLOM systems unwanted or impossible.

Management by Commercial Enterprises	
Advantages: ✓ direct financial self interest is the basis of their involvement (in the short term);the responsibilities are clear; two parties, business agreements, no voluntariness, sanction instruments; ✓ used to take initiatives to improve exploitation.	Disadvantages: ✓ without adequate agreements and control the situation may get out of hand: forcing up of prices, neglecting system maintenance (short term interest), non-fulfilment of (financial) obligations, abuse, mutual blackmail, etc.

Management by (semi-) Governmental Services	
Advantages: ✓ the service may dispose of the necessary capacity and means.	Disadvantages: ✓ the distance to the village is long, resulting in communication problems, travelling times and expenses, minimal involvement of the service and thus long breakdown times; ✓ the village fully depends on the bureaucracy, the people responsible are not approachable or cannot be called to account, the village can easily be blackmailed by maintenance teams;
✓ the limited availability of the system will lead to problems with the village: their refusal to pay certainly in case of water rate increases, will result in bad maintenance and the system further degrades;	✓ when the means of the service decreases, a whole range of systems will collapse; ✓ by lack of user involvement there will be no social control in case of misuse, theft, vandalism..

Figure 21: A comparison of management systems as analyzed by Besselink (1992).

5.3 The right balance

I want to discuss the extent to which VLOM may be effected according the dinstinction I made in *community performance* of maintenance(1) and *community management*(2) of maintenance.

1) Several maintenance tasks are that simple that communities can *perform* them without any training. (Only) sensitization is needed, to convince the people of the importance of performing them. Such maintenance tasks are primarily preventive, such as considering area cleanliness, the upkeeping of a fence, or guarding against abuse. Agencies might use penalties to *force* communities to perform maintenance tasks, but this would be circumcising the sensitization process, and, when handpumps are (declared to be) community property, it is not justified.

Although the ability of local caretakers to perform maintenance increases with training and education, certain maintenance tasks will be that difficult (e.g. lifting of the rising main), that it would be better to remain performing them by external agencies; backup. According to my view such backup can best be performed by area mechanics, living in the approximate surroundings, which the communities can contact in the case of urgency. Ideally such repairmen are autonomous, dispose over sufficient skills, connections and transportation facilities to perform *all* maintenance. People with some technical background might be trained for such jobs; if this would not be possible, communities should have the possibility to contact some other external agency in urgent cases.

Criticism of the VLOM-camp on such systems is aimed at the remaining dependency of communities. What if repairmen would refuse to repair community handpumps because of some quarrels? What if they would not be motivated? Maintenance would not be of their own interest, other than maybe obtaining some money. What if repairmen would misuse their position and demand usurious prices for their performances? What if the villagers have a conflict with the repairmen, not trusting him and accusing him of unwillingness, and malevolence? (Besselink,1992; Roy,1984). Such criticism may be true, but the extent to which this actual causes problems has to be questioned. Besides, comparable conflicts may also exist *within* the community; and it would be better to provide for backup service in such a way, than to ignore the need for backup.

Sanjit Roy, the director of the Social Work Research Centre (Rajasthan, India), is one of the authors expressing the disgust of dependency on external parties. According to him every maintenance system other dan VLOM is an example of a design by people who do not have confidence in communities (Roy,1984). His agency installs India Mark II (!) handpumps, which are entirely maintained by local mechanics, which received a three months training to do so (Wierema,1987). But it remains to be questioned whether there exists a kind of backup in these cases, or not. Most probably a minimal though basic need for backup remains, even in these cases. According to me, this is not too problematic, as long as communities are the ones managing the systems.

2) Communities' inability to *manage* maintenance would be a much more structural limitation of VLOM. Such inability would primarily be the result of problems on the software-side; especially of the community organization and participation level. Permanently leaving management of maintenance to external agencies has appeared to be improper. Community development, enforcing the organizational skills and community involvement, is therefore essential for effecting sustainable VLOM. But this is a long term-process. Agencies,

not having the willingness or means for long-term community-development, should in such cases wonder whether to supply handpumps or not. Installing handpumps with the communities managing maintenance on paper, but without considering managerial problems, is like ostrich policy.

Hence backup remains essential in practically all cases, to prevent programmes from failure. This has also been a conclusion of the 'Workshop on national strategies for operation and maintenance of rural groundwater supplies', Malawi, 1986: "*Communities must be involved to the maximum extent possible in the planning, siting and construction of their wells and boreholes and then should undertake the management of their water supply, including the execution of routine repairs and the purchase of routinely wearing spares parts. Government* [agency] *has a major role to play in extension and training, and the execution of major repairs that communities cannot handle themselves.*" (gov.of Malawi,1986).

According to Besselink backup of governments (or agencies) should be:

✓ to take the initiative, regulate, supervise, but not: manage, repair nor maintain the pump systems.

✓ temporary (financial) support in case of major problems

✓ if necessary taking the initiative for the maintenance of the borehole, and funding for the future extension or replacement of the system (Besselink,1992).

Even when backup service has been provided Hofkes expects high failure rates in early stages of development. "*In most developing countries it is not reasonable to expect small rural communities to fully maintain their handpump as envisaged in the maintenance system as it should eventually developed. Frequently the direct result of such a system will be a large number of handpumps out of operation..*". Hofkes pleads for a higher level of intervention in initial stages, i.e. after the installation of handpumps. These interventions should lead up to eventual VLOM in future (Hofkes,1983). Agencies could provide for community development in such initial stages. Cleaver (1991) states that there is proof that community maintenance may improve over time; thus pleading for higher levels of intervention in initial stages.

Construction costs however will be considerable higher than of centrally maintained handpumps, when VLOM should actually be effected in such a way. Van Wijk mentions an increase in construction costs of 13-17% (van Wijk,1987).

Sketches of the performance of both centralized maintenance and VLOM over time are sketched in Figure 22. These sketches are indicative only, and no quantifiable data may be derived from them. Exact courses of performance can only be evaluated retrospectively, and differ from place to place according to the local conditions. Notice that, in the case of VLOM, solely the performance of VLOM is figured, and not of the initial support of agencies, which is needed to effect VLOM.

Hence the extent to which VLOM is possible differs; over time, as a result of community development and the success or failure of projects; and over place, as a result of local conditions. Theoretically this extent may differ from almost 0% to maybe 100% in exceptional cases. Passing the extent to which VLOM is possible (i.e. to exceed community capacity) results in a rapid decrease in performance; inability of users to perform requested maintenance tasks finally leads to the rejection of the supply.

In planning and implementing for maintenance, it is therefore of the highest importance to assess what the optimal percentage VLOM is; at present, and in future after community development.

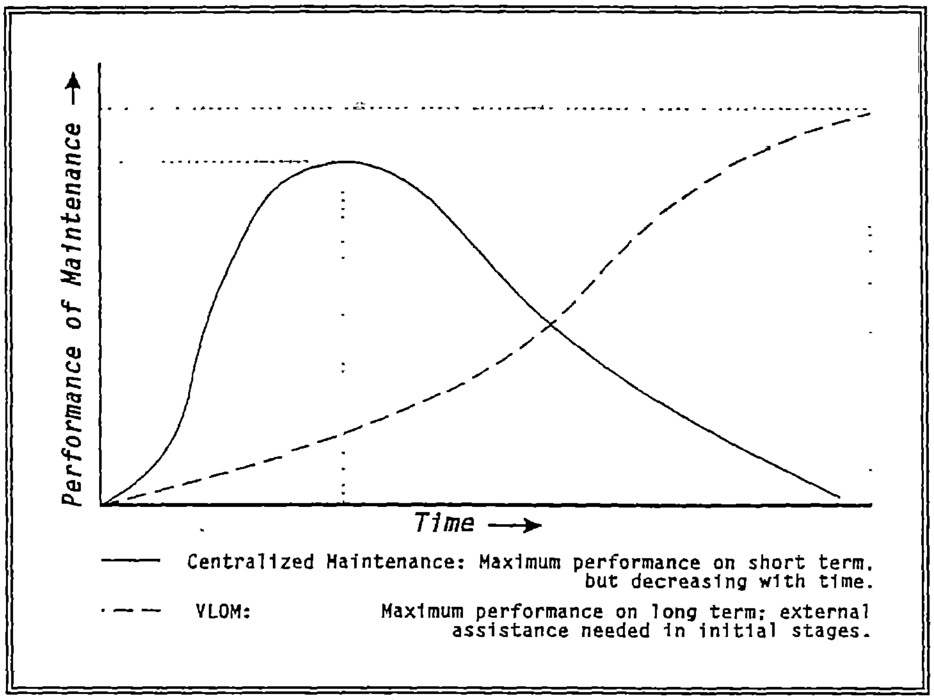


Figure 22: Indicative sketches of the performance of VLOM and centralized maintenance over time.

6 HANDPUMPS ON EXTRA-DEEP WELLS

6.1 Technological backgrounds

When the pumping lift increases, discharge decreases; as long as the power input and efficiency remain the same. The relation between discharge and lift is the following:

$$Discharge(l/h) = \frac{Power(W)\ x\ Efficiency(\%)\ x\ 36}{Lift(m)\ x\ 9.81}$$

The efficiency largely depends on the pumping lift, and differs for every pump. Handpumps will generally be designed in such a way that the efficiency is highest at pumping lifts for which they are designed. Typically the efficiency has a strong decline at deeper settings, until it is zero. There is a distinction between the *volumetric efficiency* and the *mechanical efficiency* (Besselink,1992).

- The volumetric efficiency is determined by the axial deformation of piston rod and rising main, Such deformation may occur as a result of the weight of the water and installation. Especially (extra) deepwell reciprocating piston pumps with plastic rising mains may suffer from low volumetric efficiencies. Typically the efficiency is between 15 and 70%.
- The mechanical efficiency is the efficiency as determined by the pump type, lift, mechanical and hydraulical friction losses, and volumetric efficiency. Diaphragm-pumps have low mechanical efficiencies, which hardly can be improved. Especially at deeper settings the discharges of such pumps are low (Besselink,1992; Fraenkel,1986).

Besselink uses the comparison of the energy input (kWh)[9] with the 'daily volume times pumping lift' (m^3 x m $=m^4$) as an indication of the efficiency of handpumps.

To some extent it is possible to adapt handpumps to specific depth ranges. It merely depends on the handpump design, which adaptions can be made. Key-factor is the change in the relation between power input and discharge, under a changing efficiency of the systems.

The next adaptions exist:

✓ The mechanical advantage, such as exist through lever or flywheel in deepwell reciprocating handpumps, may be adjustable by a variable handle length. Children might like longer handles (smaller stroke, smaller power input), while adults might like shorter ones.

✓ The possibility may exist to adjust the mechanical advantage mechanically, such as in the case of Volanta handpumps.

✓ The mechanical advantage of progressing cavity pumps may be adjustable by a change in the gearbox. In the case of the MONO-handpump, an optional gearbox of 1:2 can be chosen for deepwells, while the standard 1:3 gearbox can be chosen for shallower wells.

✓ There may be an option for choosing different piston and/or riser diameters. In general risers with smaller diameters are more appropriate for deeper SWLs.(Arlosoroff,1987; Besselink,1992; Besselink,pers.com; Calorama,1992/1993; Donaldson,1988; Reynolds,1992).

[9] Power input of adults may temporary be as much as 100-150 Watts. Average power inputs however will be not more than 50-75 Watts, depending on the person(s) pumping and the specific pumping conditions (Arlosoroff,1987; Besselink,1992).

The yield/stroke ratio in deepwells will generally be lower than in shallow wells, as more energy is needed to lift the water to the surface. High yield/stroke ratios in deepwells would require power inputs too large for smooth operation. By increasing the mechanical advantage, the yield/stroke ratio will be lowered (Donaldson,1988; Besselink,1992).

6.2 Nature of the problems

At the present level of handpump technology, no technological problems have to exist in designing handpumps for SWLs up to 40m depth (Besselink,1992). A considerable and still increasing number of handpumps for such depths (deepwell-handpumps) has been developed, of which the newest ones mostly 'VLOM-handpumps'. The appropriateness of such pumps depends on the local conditions; in most cases the diversity of handpumps allows for an optimal pump selection.

However, with increasing depth of the SWL difficulties seem to increase:

✓ A *higher power input* is required to obtain the same quantity of water, due to an overall decreasing efficiency; consequently *more time* is needed to obtain this quantity;

✓ Consequently *a smaller number of users* can make use of the pump, and the *costs per capita will be higher*; the more because an increasing depth raises the price of handpumps and *breakdowns occur more frequently* at deeper settings (e.g. wear of bearings);

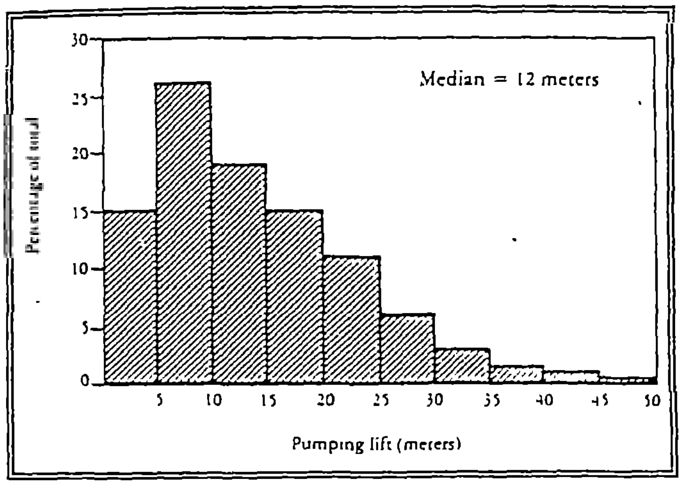
✓ The *weight of the installation* disables maintenance without heavy equipment, especially if the rising main has to be lifted;

✓ Depending on the riser used, the weight of the installation and the length of the riser allow for several *technical problems*, such as fatigue, stress, deformation, stretching (creep) and snaking. With increasing depth the *deformation of plastic risers lowers the volumetric efficiency*, resulting in a zero-discharge at certain depth.

It is therefore no surprise that the performance of handpumps on *extra-deep wells* (SWL$\geq$45m) has been characterized by many problems; low availability of handpumps due to frequent breakdowns, failure of projects, obstruction of water supply in general, and of VLOM. The non-existence of handpumps for extra-deep wells is an additional and decisive factor. Due to the technological problems, and probably due to the fact that manufacturers do not want their handpumps to receive bad ratings. An example might be the SWN81 (or recently SWN90) handpump, which is claimed to function up to 80 meters SWL or more, while the manufacturer personally does not advise usage below 60 meters SWL (Besselink,-pers.com; Bonnier,pers.com; Calorama,1992/1993). Only recently some handpumps have been developed, which performance allows for usage on extra-deep wells.

Before discussing the problems more abundantly, I want to discuss another and all embracing question: are the problems such as occur with extra-deepwell handpumps that important; are extra-deepwell settings that common?

6.3 The existence of extra-deep wells



SWL	Frequency
≤20m	75%
≤25m	85%
≤50m	98%

Figure 23 & 24: Pumping lift frequency distribution in field trials of the Handpumps Project (Arlosoroff,1987).

Figure 23 and 24 display the pumping lift frequency distribution in field trials, such as found by the Handpumps Project. The figures reveal a very low frequency of extra-deep wells. 98% of the wells involved a water level of less than 50m. David Grey: "And yet we still hear people saying that the big problem for handpump design is the deep setting... I think we need to get it into our heads that if we solve the problems to 50m, we have solved 95-98% of the problems that exist" (Arlosoroff,1987; Grey,1987).

Well, I doubt about the mentioned frequency of extra-deep wells. At first, It would be better to state that 98% of the wells *considered*, involved water levels of less than 50m. Wells are often not very common in areas with extra deep water levels. The mentioned frequency does not consider the existence of extra-deep water levels world wide, but rather the existence of wells, as a function of this water level.

In other words: *the non-existence of wells with extra-deep water levels might even indicate the urgency of developing appropriate pumping systems for extra-deep wells.*

Secondly, even if the water level in 98% of the wells in rural areas would be less than 50m, the remaining 2% would still be good for about 40 million people worldwide. Maybe it has to be wondered which urgency would be given to the extra-deepwell cases when it would be a problem of western countries. Besides, IDWSSD-goals would not be fulfilled without considering the extra-deepwell cases. Skipping of communities with extra-deep water levels might even be considered as a kind of discrimination. It might reveal a kind of indifference of whom are going to be supplied, as long as some people are supplied.

It is my conviction that the occurrence of extra-deep water levels is more common than assessed. I already indicated that the KHCDP, installing handpumps in a considerable part of Ethiopia, drilled wells of which 36% have a water level of 45m or more. Another example is the Dosso-project in Niger, where extra-deep water levels are very common: The wells of a hundred handpumps have a mean SWL of 60m, with a maximum SWL of 99m (Dekker,pers.com; Besselink,1990).

The attention given to the extra-deep well issue in practise may be an indication of its importance. Besides, all over the world water levels are dropping and aquifers are drying up, which might imply that the frequency of extra-deep water levels will increase with time.

6.4 Handpumps on extra-deep wells?

Given the fact that extra-deep water levels exist, there are several options how to deal with such cases. Implementing agencies should wonder whether it would be wise to install handpumps on extra-deep wells, whether alternatives on handpumps should be used, or whether projects should be abandoned. The Handpumps Project advised not to install handpumps on wells deeper than 60m SWL, because of the mentioned technical problems and constraints to VLOM (Arlosoroff,1987). Wells with deeper SWLs should be provided with alternative water lifting devices, such as submersible pumps, or should not be provided with any water lifting device other than for instance buckets. However, alternatives are often much more expensive (beyond the communities' capacities), may create dependency relations considering maintenance and power, or may compromise the quality of the supply. In cases in which handpumps are considered to be the optimal option for rural water supply, the selection of alternative devices due to the SWL would in fact be a kind of compromising. Ideally, appropriate handpumps would exist to lift water from extra deep water levels. The lack of such handpumps severely hampers water supply in extra-deepwell cases.

6.5 VLOM of extra-deepwell handpumps

The motivation of community members to keep handpumps in operating condition may increase with increasing depth of the SWL. Pacey already mentions a higher motivation as one of the reasons for success of an UNICEF deepwell handpumps project in Bangladesh, as compared to the results of other projects (Pacey,1977). Morgan reasons the same, at least about limited community participation: "*Where handpumps are essential for survival, in areas where water-tables are deep and there are no alternatives, communities are far more willing to contribute their time and even their money to keep pumps working..*" (Morgan,1989(1)). Dekker observed similar cases in the Dosso-project, Niger. In extra-deepwell cases, users seemed to appreciate the well more than in shallower water level cases: it is a rigorous job to lift the water with bucket and rope when the water table is deep. There seemed to be a positive correlation between pump-usage and depth, and consequently a positive relation between usage and maintenance costs (Dekker,pers.com;Dekker,1993). Similar facts appeared from the Fonko town, Ethiopia, where one extra-deepwell handpump (SWL 68m) seemed to be appreciated very much, and the pump was intensively used. A similar handpump on a 85m SWL well in the same village appeared to be unaccepted, and left useless. *Probably motivation increases with depth, but has a sharp decline when the SWL becomes too deep* i.e. when the required power input becomes too high, or the discharge too low, in the eyes of the community members.

Although the community motivation seems to increase with the SWL, the possibilities for VLOM are obstructed. Hofkes states that the lifting of risers of handpumps on extra-deep wells can best be left over to technicians (Hofkes,1983). This is particularly true considering the lifting of GI/SS risers, necessitating the use of tripods. Schoolkate similarly states that deeper SWLs more intensively require regional maintenance teams; and that this need can probably not be overcome easily (Schoolkate,1991). Such dependency on external maintenance teams (i.e. in the lifting of risers) would be limited in the case of OTCs, because OTCs would allow for replacement of downhole wearing parts without lifting the rising main; standardizing on OTC-handpumps would therefore be advantageous.

6.6 The use of plastic risers

Research on handpumps for extra-deep wells has largely been aimed at preventing or solving riser (and rod) problems. Especially research has been made on the subject of plastic (μPVC) risers. Next to the advantage of corrosion resistance, the low specific gravity of plastic would be advantageous for handpumps on extra-deep wells. Inter Action Design (IAD) and the UNDP/WB Handpumps Project have been researching this matter. The research on the use of plastic pump-rods has largely been comparable. An outline of the research:

While the static and quasi-static[10] forces in a handpump rising main can be calculated easily, the dynamic forces[11] are much more difficult to predict theoretically. At low pumping frequencies (smaller than about half the resonant frequency of the rising main), stresses on pump rods and rising mains appear to be accurately predicted by quasi-static approximations; At higher pumping speeds however, dynamic forces add considerably to the total stress. The lifetime of risers will most of all be determined by these dynamic forces: the way and extent in which the forces vary throughout the pumping cycles. In most cases, the maximum stress occurs at the bottom of the rising main. It has appeared that the absolute levels of stress in rising main are considerably less than the ultimate tensile strength of μPVC. It is therefore not surprisingly that in research, with standard rising main pipes, hardly any broken rising main parts have been observed. Failure is more likely to occur as a result of fatigue. Test results have shown higher frequencies of secondary stress variations, determined by the delivery and return strokes; these dynamic forces are the main cause of fatigue, rather than maximum stress.

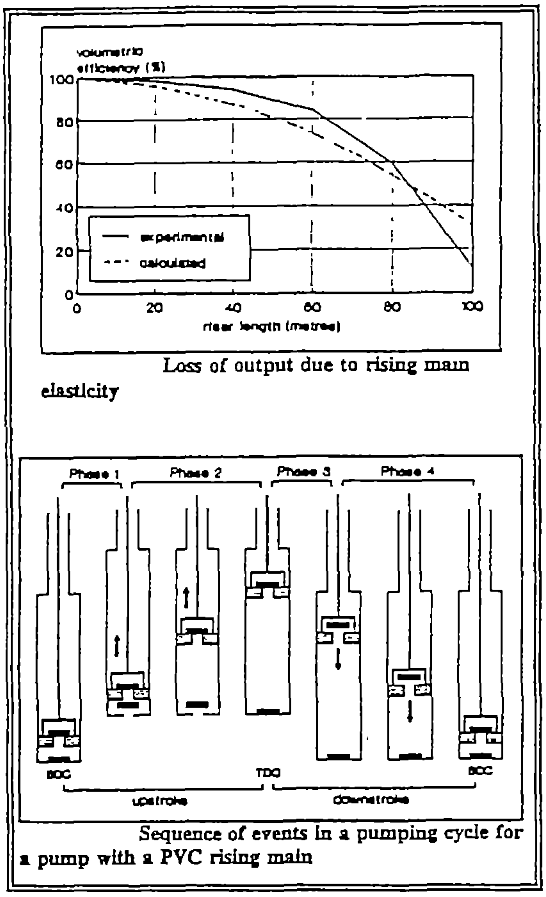
How do these dynamic forces develop? At the start of the upstroke, a pressure front will develop above the piston. Water being almost incompressible, the riser will expand to accommodate it. This pressure front moves up the rising main at a speed determined by the pipe characteristics (typically 400m/s), and is reflected back down at the top. After a few pumping cycles, a complex pattern of pressure waves will have been developed: dynamic forces, which determine the riser behaviour and cause fatigue. It is difficult to predict the likely fatigue life of rising mains. It will depend on specific characteristics, such as the composition of the raw material, manufacturing method, quality, the addition of stabilizers and/or lubricants in processing, and of fillers and rubbery materials to improve impact strength.

Although levels of stress are generally equal to the levels of other deepwell reciprocating pumps, rotary/flywheel configuration pumps give the lowest values for deflection of the riser main, due to the absence of stops and simple harmonic motion. However, advantages are modest compared to lever-arm reciprocating handpumps, at least if these are used without banging the handle on its stops.

Swinging and snaking of rising mains and cylinder proved not to be a frequent

[10] (quasi) static forces: the 'dead-weight' of the components and of the water.

[11] dynamic forces: forces involved in the accelerating the pump rod and the water column, friction at the piston seal, shock loads resulting from the pump handle hitting its stops and other possible factors.



Loss of output due to rising main elasticity

Sequence of events in a pumping cycle for a pump with a PVC rising main

Figure 26: Stretching and relaxing of µPVC rising mains, consequently the loss of volumetric efficiency, and its relation to riser length(Reynolds,1992).

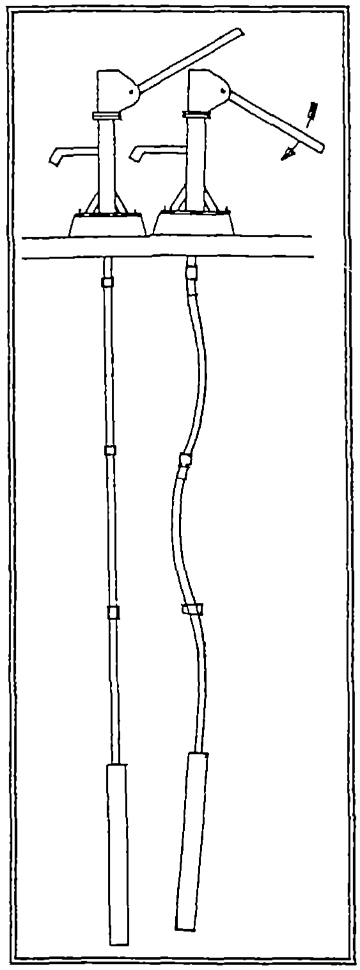


Figure 25: Swinging and snaking of rising mains (Calorama,1992/1993).

problem, as long as it is limited/prevented by the installation of centralizers/ guides around the riser. These minimize the bending stress fluctuations (and hence fatigue), though they do not prevent buckling when compressive stresses occur. Figure 25 gives an idea about typical µPVC riser behaviour. If swinging and snaking are not prevented, this might easily lead to leaking sockets and/or broken riser couplings.

Next to swinging and snaking, plastic risers might elongate under continuous load. The elongation (or creep) might be as much as 0.1% -0.2% per year at 20°C. The largest effects of elongation will happen at large riser lengths. This might be a problem, as long as no measures are taken to prevent stroke reduction. Allowing for elongation (i.e. designing the cylinder with a longer stroke length than actually needed, to prevent it from 'topping' even after years (of elongation)), might prevent problems. If not, stroke length might even become zero, hence disabling pumping completely.

Pipe stretching and relaxing, as a function of the pumping rate and resonance frequency of the riser, is more likely to be problematic. As indicated in Figure 26, it is sufficient to reduce considerably the actual stroke_length, and therefore the amount of water

delivered. The volumetric efficiency is reduced in this way. Due to the low resonant frequency of μPVC rising mains, resonance may even occur at normal pumping rates. With an increasing riser length, this problem will be worsened, resulting in a 0% volumetric efficiency at certain depth. Designing/incorporating cylinders with a comparatively long stroke and small diameter (i.e. maximizing pump stroke/piston diameter ratio) would minimize the effect of this problem.

The riser joints appeared to be the weakest part of the plastic rising main. Fatigue is most probably to occur at these joints. Cemented joints have appeared to be the best solution to overcome fatigue problems. In the Dosso project, making use of Volanta handpumps with μPVC risers and cemented joints, there have been severe problems with these riser couplings. Fractures frequently occurred in the middle of the sockets along the riser surface where two riser parts join (see Figure 27). These problems have been solved by cementing the riser parts in the socket while keeping a distance of at least 10mm between the ends of the riser parts. Evidence from the same project proved the success of this strategy (Besselink,pers.com; Besselink,1990; Dekker,pers.com;Dekker,1993). It is surprisingly that general existing problems with μPVC risers at depths $\geq$40m hence seem to be overcome. The fracturing of joints has been a frequent reason why manufacturers remained using GI or SS rods, or rejected handpumps as an appropriate device for pumping water from extra-deep wells (Besselink,1990; Besselink,1992; Dekker,1993; Reynolds,1992).

Although the manufacturing of plastic risers is considered to be of great importance to VLOM, the corrosion resistance of the material is probably the more important advantage. Plastic risers may be the only option in extra-deepwells with aggressive water. At least when sustainable supplies should be effected. The development of OTCs enables communities to replace downhole wearing parts without the lifting of the rising main; hence the weight of the riser does not matter very much for VLOM, as long as OTCs are used. But when the riser has to be lifted and replaced in maintenance, plastic risers are certainly advantageous; but, such as mentioned, it should not be expected that communities perform such maintenance easily. Mostly high skilled personnel remains necessary in lifting/re-installation rising mains.

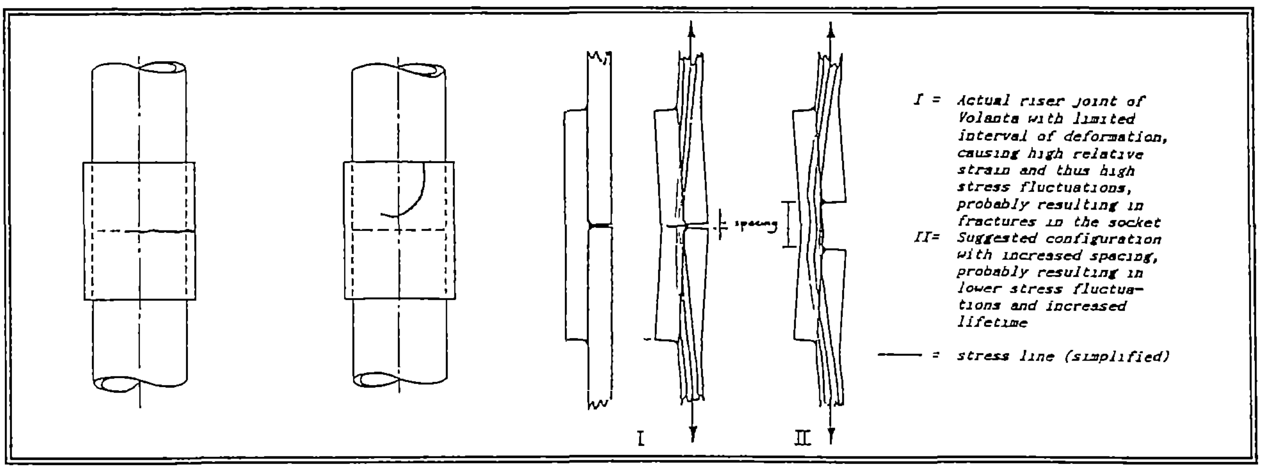


Figure 27: Fractures in the cemented riser joint of the Volanta, occuring at deep installation (Besselink,1990).

6.7 Extra-deepwell handpumps

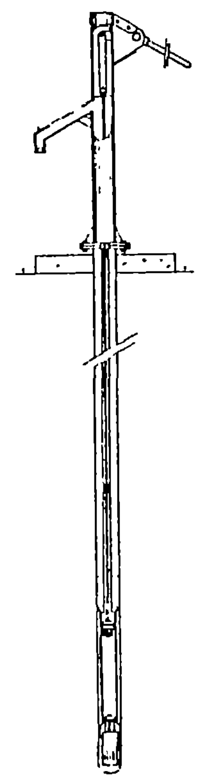
There exist several handpumps which can lift water from extra-deep wells; although the most are certainly no VLOM- handpumps. I would like to discuss some pro- and contras of these handpumps, and indicate the ones that would probably be the best choices, considering their performance, price, and possibilities for VLOM.

In this paragraph I will discuss some handpumps which can lift water from extra-deep wells; the mentioned handpumps are pumps of which it has been reported that they are used on extra-deep wells. There may exist other handpumps which have potential to lift water from extra-deep wells, but which are not widely used for this purpose, and have therefore not been researched adequately. The original Zimbabwian bush pump may be an example; although the GI risers of this pump do certainly not allow for sustainable performance and VLOM.

The extra-deepwell handpumps which I want to discuss are the following:

1) The Aquamont
2) The extra-deepwell India Mark II
3) Kardia
4) The Mono
5) The Moyno
6) The Pulsa
7) The SWN81\90
8) The Vergnet
9) The Volanta

6.7.1 The Aquamont



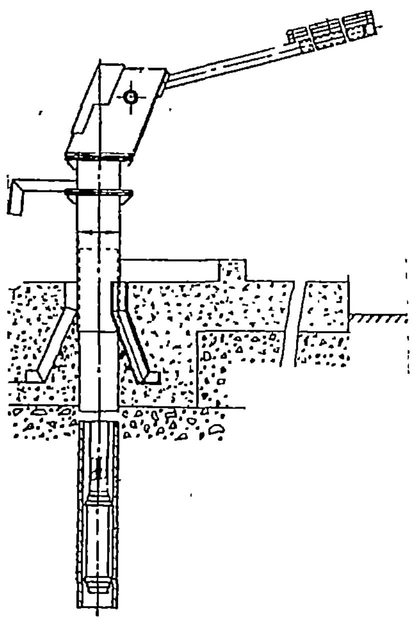
The Aquamont

The Aquamont is a reciprocating deepwell piston pump, manufactured in the UK. The pump has originally been intended for SWLs down to 90 metres, and has been tested in 1988. The pump uses GI rising mains, with μPVC as an (unconsidered) option, and a glassfibre reinforced epoxy resin cylinder. This cylinder, employing nitrile seals, is claimed to have both low wear and friction, allowing for pumping from extra-deep wells. Original tests revealed a meagre manufacturing quality, and a low MTBF. As according to the manufacturer, these problems have been solved. Efficiency of the handpump is very good at deep water levels (η80%; 100W,45m SWL). Initially the pump appeared to have a poor resistance to contamination. The handpump, not being supplied with an OTC, requires the lifting of the entire GI-rising main to replace below-ground components; and these *do* need regular replacement. Next to this constraint to VLOM, it is not easy to replace handle bearings under field conditions. The handpump is therefore not suitable for VLOM, and has to be maintained in a regional or centralized maintenance system. Below ground components of the Aquamont do not allow for manufacturing in developing countries.

The mentioned characteristics are derived from CRL-data only; the pump has been send to Cameroon, Malawi, Zambia and Burkina Faso for limited field tests; for the time being no data on the field testing are available. Due to its bad VLOM-qualities, the handpump is not recommendable. Besides, it is uncertain what the price of the pump is, whether

the pump is still in production, or remains to be produced in future. The manufacturer remains silent (Arlosoroff,1987;Mills,1988; Reynolds,1992).

6.7.2 The extra-deepwell India Mark II



The Extra-Deepwell India Mark II

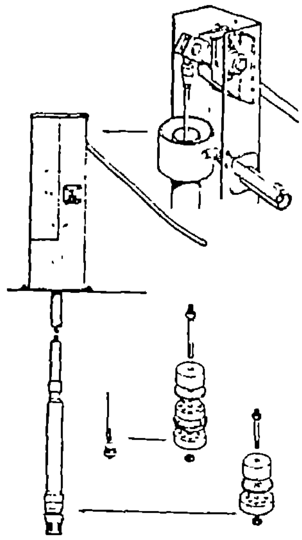
The extra-deepwell India Mark II is an adapted version of the well-known India Mark II. A report of the government of India on the subject of India Mark III handpumps makes notice of a non-VLOM India Mark II-handpump, with 50mm ID[12] cylinder, 50mm GI rising main and a Mark II pumphead with 10:1 mechanical advantage (gov. of India,1990). In 1992, the Bureau of Indian Standards has standardized on another configuration, known as the extra-deepwell India Mark II. This pump uses a 63.5mm ID brass lined cylinder, 32mm ID GI-rising main, 12mm GI/SS rod and a somewhat adapted Mark II pumphead. To adapt the handpump to deeper SWLs, counter weights can be assembled. The report makes notice of *cylinder settings* up to 90 meters depth (BIS,1992). In recent tests this India Mark II revealed a very high efficiency, as compared to other extra-deepwell handpumps (η65%,100W,45m SWL; η65%,100W,-60m SWL; η66%,100W,90m SWL) (Besselink,1992). With these ratings the extra-deepwell India Mark II has the best performance of all handpumps at SWL$\geq$70m. This is partly the result of the usage of GI-risers, as compared to the μPVC risers of its concurrents: GI does not suffer from elongation, which means that the volumetric efficiency remains higher. No field tests have been published on the reliability of this pump. The reliability of some components may however be compared with the standard India Mark II. The cylinder is almost identical to the Mark II cylinder (three-part piston seals), but more efforts have been done to make the wearing components more durable; e.g. the use of nitrile rubber (abrasion resistant) seals in stead of leather ones. The pumphead has large similarities with the standard India Mark II, but is more sturdy, designed for usage at extra-deep water levels. For this reason, the handle is equipped with a T-bar and counterweights. Documentation about the reliability of the riser concerning fatigue is not beforehand, and has to be researched. Because of the use of GI risers, the pump is not recommendable in aggressive groundwater zones; at least not in the mentioned configuration (Besselink,1992; BIS,1992). As equal to the India Mark II and III, the handpump can adequately be manufactured in countries with a medium level industry.

Because of its similarity to the widely-used standard India Mark II handpump, this extra-deepwell version may be the best choice when there has been standardized on the India Mark II. But it requires maintenance by centralized/ regional maintenance teams and non-aggressive groundwater. It may be better to use such a non-VLOM handpump which is known and which spare parts are available, than to use an unknown VLOM-alternative. If the

[12] ID: Internal Diameter.

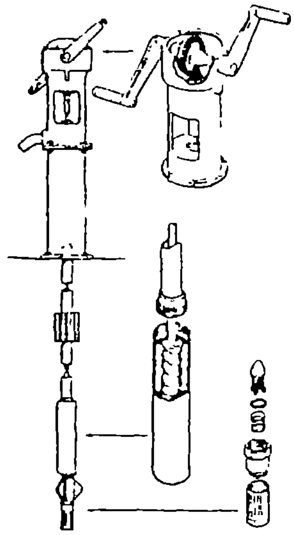
highest priority should be given to VLOM, the need to standardize is not of importance, or groundwater is aggressive, the extra-deepwell India Mark II would not be appropriate. Maintenance would even be a rigorous task for high-skilled and equipped personnel, due to the enormous weight of the belowground components; and aggressive water would result in poor reliability ratings.

6.7.3 The Kardia


The Kardia.

The Kardia is a deepwell reciprocating piston pump, which has been tested by the CRL. A summary of the testing results has been published by the UNDP/WB, in the Handpumps' Compendium. The pump has originally been designed to lift water from 6-30/40m SWL only. Since the testing time some modifications have been made, which make the pump appropriate for extra-deep water levels. The extra-deepwell version is supplied with 50/60mm ID μPVC riser; the larger one allowing for better performance in shallow well cases, while not significantly compromising the performance in the extra-deepwell cases. An 63mm μPVC cylinder -no OTC- is used. The pump is highly corrosion resistant, and therefore usable in aggressive water; abrasion resistance is adequate; Reliability has yet to be tested. Performance of the Kardia seems to be good. As equal to the performance of the Volanta at SWLs$\geq$40m, it has the next efficiencies: η74%,100W,45m SWL; η70%,100W,60m SWL; η55%,100W,90m SWL. Due to the μPVC below ground components, no lifting equipment is needed to maintain below-ground components; however, below ground wearing components cannot be replaced without lifting the whole rising main; for this reason VLOM is somewhat obstructed. But maintenance can easily be performed by area mechanics/ bicycle repairmen. The Kardia can adequately be manufactured in countries with a medium industrial base; though quality control and high skilled personnel are needed.

6.7.4 The Mono

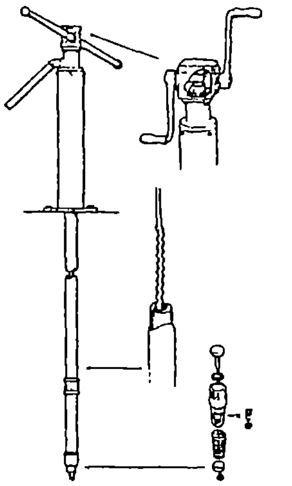

The Mono.

The Mono is a progressing cavity handpump, which is manufactured in the UK, and has been used on extra-deepwells since the seventies; in fact it has been one of the first handpumps which could lift water from extra-deep wells. The extra-deepwell version of the Mono is supplied with a 2:1 gearbox; 63.5mm GI rising mains, GI/SS rods and a double helical steel rotor/triple helical elastomeric stator. It is one of the few handpumps that has also been tested by the CRL on a 60m SWL setting. Test results can be found back in the handpumps compendium. As characteristic for progressing cavity handpumps, efficiency is low (η59%,100W,45m SWL; η59%,100W,60m SWL). Power input necessary to lift water increases considerably with depth. The abrasion resistance is (very) high; plastic risers cannot be used for this kind of pumps; the Mono has GI risers, and the pump is consequently not suitable for usage in

aggressive water. Adequate reliability ratings have been given to the pump for lifts up to 45m and outputs of $4m^3/d$; The reliability seems to have a sharp decline with increasing SWL, as appeared from field data. It is an advantage that the pump allows for two person operation, hence facilitating pumping when the required power input is high. Typical problems are the fast wearing of bearings and gears, and the loosening of pump rods. Maintenance is complex, and requires special skills and equipment. The Mono cannot be manufactured in developing countries. Although the ratings may be sufficient for operation at shallow/deepwells settings in centralized maintenance, the Mono is not one of the best extra-deepwell handpumps at the moment, and certainly no VLOM pump. Agencies might remain using the Mono for the sake of standardization, or familiarity with the pump. On the long run however, the pump would not be an appropriate one (Arlosoroff,1987; Besselink,1992; KHCDP,1992; UNICEF,1991).

6.7.5 The Moyno

In fact the same is true for the Moyno handpump, also a progressing cavity handpump, made to the image of the Mono, and introduced as an improvement on the Mono handpump. This Canadian handpump received the same ratings as the Mono. An double stage pumping element allows for pumping lifts up to 90m SWL; the handpump is very robust; uses GI risers/rods, a chrome/nickel plated SS rotor, and gunmetal footvalve. Its efficiency at 45m SWL is more or less conform the Mono: η58%,100W power input. Though disliked by many users, the handpumps is beloved in some countries/areas. Although field data do not allow for a comparison, the Moyno is probably somewhat more suitable for deeper SWLs than the Mono, because of a somewhat higher MTBF in extra-deepwell cases. The disadvantages of the pump are equal to the Mono; the pump is also not suitable for VLOM. The Moyno is out of production yet (Arlosoroff,1987; Besselink,1992; Schotanus,-pers.com; UNICEF,1991).

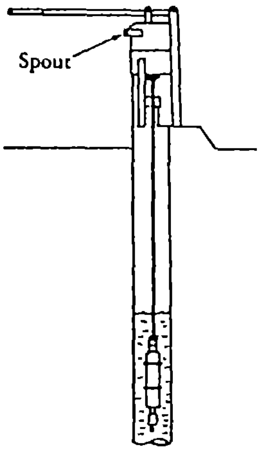

The Moyno.

6.7.6 The Pulsa

The Pulsa is a relatively new handpump, which is comparable to the Vergnet handpump. It is a lever-operated deepwell handpump which works via a principle of oscillating water columns. It compromises an above ground SS-component, containing a piston actioned by a lever handle; and a lower part under the SWL, which is in fact an elastic diaphragm, with an internal volume of water increasing under increasing hydraulic pressure. Both components are connected via a single flexible hose: This enables installation in unlined and even curved borewells. Depending on the borewell diameter, several handpumps may be installed on every well. The efficiency of the pump largely depends on the speed and rhythm with which the handle is operated. Operation may be difficult in initial stages of usage, if the users still have to get used to it.

The Pulsa has a comparatively low discharge, only about 50-75% of the discharge of conventional reciprocating deepwell handpumps. The Pulsa has the lower discharge rates of all other handpumps mentioned in this chapter; only at settings deeper than 60m, the standard

Vergnet (4C) has worse rates; the Vergnet 4D however performs better. The Pulsa has a mechanical adaption to larger depths: the number of elastic elements in the cylinder is reduced at larger heads. The Pulsa has an efficiency of 41% at 100W power input and 45m SWL setting; this efficiency is 43% at 60m SWL. An advantage of the Pulsa, as compared to the Vergnet, is the fact that it is less sensitive to cultural objections. Another advantage is the option for two-person operation.

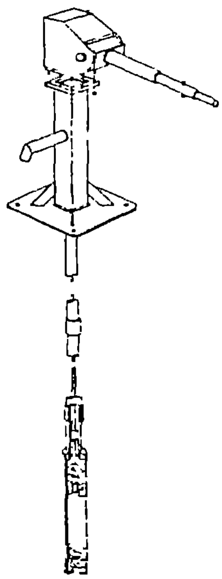


The Pulsa.

Reliability of the Pulsa has not yet been tested profoundly. The pump is abrasion and corrosion resistant and allows for VLOM adequately. The cylinder cannot be manufactured in developing countries, and a medium level industrial base is needed to manufacture other handpump components. As with the Vergnet, replacement costs of the cylinder/diaphragm are very high, which certainly puts some constraints forward in the case of VLOM. Under certain conditions, the Pulsa may appear to be advantageous (e.g. unlined or curved borewells, aggressive water); At larger depths, the Pulsa may be preferred over the standard Vergnet, although standardization would probably not make a shift from the standard Vergnet to the Pulsa advantageous (Arlosoroff,1987; Besselink,1992).

6.7.7 The SWN 81/90

The SWN handpumps are deepwell reciprocating handpumps, manufactured in the Netherlands, and frequently used in some (especially East-) African countries. The Shinyanga project (Tanzania) is probably the best known project using SWN handpumps. SWN handpumps are claimed to be *the* African handpump. Most typically is the *strong-as-a-tank* approach in design; it has been the intention to design all wearing parts with a design-life of at least 10 years. The SWN-81, and recently the SWN-90, have the capacity to lift water from extra-deep wells. The SWN-81 handpumps have SS 40/50mm ID cylinders, thick walled 48/36mm μPVC risers, 10mm SS rods, and extendable handles. This pump has been claimed to function well till SWLs of 80m. The SWN90 handpumps have comparable specifications, but are designed for SWLs up to 60m. In the first years of the Decade there have been some problems, such as with the rod and riser couplings, and the strength of bearings. But feed-back from field-practise has contributed largely to the quality and robustness of the handpumps manufactured nowadays. SWN pumps are both corrosion and abrasion resistant. Although the SWN80[13]/81 pumps have originally been rated to have a meagre reliability, the present design most probably allows for one of the most reliable handpumps worldwide; with the big disadvantage that one has to pay for it. SWN pumps have somehow

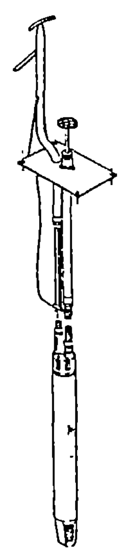

The SWN 81.

[13] The SWN80 being an shallow-lift version of the SWN81.

been designed according to the maintenance-free concept -designed to function well over a 10 years period almost without any maintenance needs-, and consequently does not allow for maintenance very easily. The maintainability is one of the shortcomings of the handpumps, especially considering the downhole components. The lifting of the rising main, although made of μPVC, requires skilled personnel; because the cylinder is no OTC and the pumphead is heavy, replacement of downhole wearing parts cannot be performed on the local level. Hence do the pumps not allow for VLOM. SWN handpumps may be maintained on regional or centralized level, with the communities participating in minor maintenance tasks only. SWN handpumps can easily be manufactured in countries with a medium industrial base.

Although the SWN81 has been designed for SWLs up to 80m or more, it has been advised not to use it for SWLs deeper than 60m, most probably because of the loss of volumetric efficiency, which occurs as a result of the μPVC riser. Besselink denotes that the discharge would be about nil when using the 50mm ID cylinder on a 80m SWL setting, while the 40mm ID cylinder would still give an acceptable output. Unfortunately no test results have been published about such settings. With other belowground components (e.g. in the case of a hybrid pump), the pumphead may be an excellent and reliable competitor of other extra-deepwell handpumps; though not allowing for VLOM, and expensive (Arlosoroff,1987; Besselink,pers.com; Bonnier, pers.com; Bron,1985; Calorama,1992/1993).

6.7.8 The Vergnet 4C/ 4D

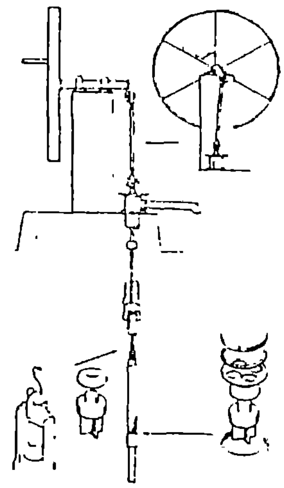


The Vergnet 4C.

The Vergnet is a typical diaphragm handpump, and has the advantage that it can be installed in bent or curved boreholes, just like the Pulsa. It is a foot-operated handpump, which might evoke cultural or practical objections. Two flexible Polyester hoses connect the above ground SS/brass primary drive cylinder and below-ground SS cylinder. The Vergnet is robust, its corrosion resistance is excellent, and its abrasion resistance is adequate; The standard (4C) Vergnet performs meagre on extra-deep wells. Its reliability at large depths is hardly adequate, which is the result of the comparatively low efficiency of the pump: η50%,100W,45m SWL; η43%,100W,60m SWL. Recently an extra-deepwell version of the Vergnet (the 4D) has been designed, which performs much better on extra-deep wells than the standard Vergnet (the 4C). The manufacturer claims proper functioning for depth ranges of 50-80/85m SWL. Rough estimates of the efficiency are as follows: η52%,100W,45m SWL; η60%,100W,60m SWL; η38%,100W,90m SWL. The 4D is more reliable on extra-deep wells than the 4C. The handpump allows for VLOM; just the replacement of the diaphragm might require some external assistance. The replacement costs of the diaphragm are high, and may be a tough burden to overcome. The diaphragm cannot be manufactured in developing countries; the pumpstand can be manufactured in countries with a medium industrial base (Arlosoroff,1987; Besselink,1992; Vergnet,1993).

Additional information about the Vergnet 4D is given in Appendix 2.

6.7.9 The Volanta



The Volanta.

The Volanta is a robust deepwell reciprocating handpump, driven by the rotation of a flywheel. It has been designed in the Netherlands. It has a cemented μPVC ID 80mm rising main, 9mm SS rods, a 50mm ID glassfibre-reinforced OTC cylinder, with seal-less machined steel piston. Like the SWN, the Volanta has been designed to be 'maintenance-free', with the one big difference that the Volanta certainly allows for maintenance. All routine maintenance can adequately be performed on the local level. The handpump can theoretically be maintained on the local level, probably without external intervention, except for the worst -and most unusual- cases. However, the pump is expensive.

The Volanta is one of the few reciprocating handpumps which has actually been adapted to extra-deepwells, without compromising on other factors, such as VLOM and corrosion resistance. It is simple to (re)install and to maintain; it is abrasion and corrosion resistant, and reliable. At 45m SWL, the efficiency is 74% (100W power input); At 60m SWL,η70% and at 90m SWL η55%. The Volanta can be manufactured in developing countries, although it might be advantageous to manufacture the glassfibre reinforced cylinder in western countries. It requires good quality control and skilled personnel in manufacturing. The Volanta is being manufactured in Burkina Faso too, which might be proof of its suitability.

Problems which have existed with the rod/riser couplings have lately been overcome, such as verified by recent field data from Niger. According to this data, Volanta handpumps installed on wells $\geq$ 70m SWL have been working over 15 months, with mean overall maintenance costs of $\pm$ US$ 150[14][15]. The pumps considered have been used intensively during this time, because of a general lack of alternative water sources. However, no exact quantitative data about usage are available (Dekker,1993).

According to Bron, and according to the CRL testings, the Volanta approaches the VLOM qualifications as one of the best of all handpumps; the Afridev and India Mark III maybe approaching the concept better; but these handpumps are not suitable for extra-deepwells. The qualities of the Kardia, a real competitor of the Volanta considering both performance and VLOM-qualities, have still to be proven. The capital costs of the handpump are high, as may be obvious in the subjoined table. This is certainly a big disadvantage; however, on the long run the Volanta might be cheaper due to its reliability, and because the handpump may be maintained on the local level. In some cases it appeared that the pump was disliked by the users, due to its operating mechanism; but this may be the case with every

[14] Maintenance costs. The pumps are maintained by a regional maintenance team. Costs are overall maintenance costs, including the costs of spares, wages, etc.

[15] Volantas lifting water from 50-60m SWL had maintenance costs of ± US$ 80; those working on a depth range of 50-60m SWL ±US$ 60; and those working on a depth range of 40-50m SWL ± US$ 20. However, pumps lifting water from shallower SWLs have been used less intensively, due to a general increase in the availability of alternative water sources. Data has been derived from a 177 handpumps (Dekker,1993).

handpump (Arlosoroff,1987; Besselink,1992; Besselink,pers.com; Bron,1985; Dekker,1993). Appendix 3 reviews some additional information about the pump.

6.7.10 Pump selection

Resuming, it may be obvious that handpumps for extra-deep wells do exist, although their capital recurrent costs are considerable higher than for standard deepwell handpumps[16]. It has to be recognized that it would probably be worse to buy a cheap and unreliable handpump, than to buy an reliable but expensive one. Economizing on capital costs may lead to bad performance and (consequently) high recurrent costs (Bonnier,pers.com; Hofkes,1983; Schoolkate,1991).

Some of the extra-deepwell handpumps approach the VLOM-status. It is a pity that only very few field data on the performance and costs of handpumps exists. In some cases, such as with the extra-deepwell India Mark II, the Kardia and the Vergnet 4D, this is not very surprising, because these handpumps have recently been designed. It may be obvious that it is not possible to indicate a world-wide best choice, due to -for instance- standardization and community factors/preference. At this moment, the Volanta will probably be the best choice, considering the technical performance and Village Level Operation and Maintenance only (leaving standardization and in-country production out of attention). The addresses of the manufacturers of the different extra-deepwell handpumps are given in Appendix 4.

Performance of most of the handpumps (except the Aquamont, SWN, Mono and Moyno) has been researched by Besselink. The estimated discharge rates as a function of the SWL are displayed in Figure 28. Next to this, estimations of the discharge rates, efficiencies and prices of the handpumps are given in Figure 29.

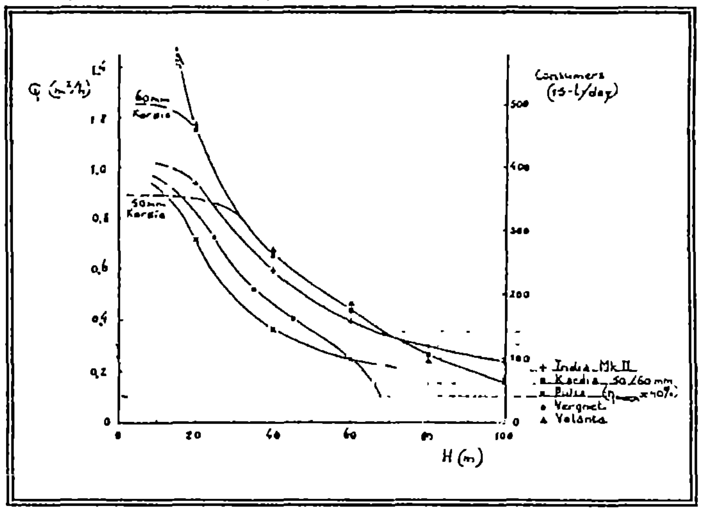


Figure 28: Estimated discharge rates of several extra-deepwell handpumps, as a function of the SWL, at a power input of 100W (Besselink,1992).

The Kale Heywet Church Development Programme requested for the research on handpumps for extra-deep wells. The selection of a handpump for this NGO may be an example for handpump selection in general.

The NGO has been using Mono handpumps for its extra-deep wells. These handpumps have appeared to be problematic on extra-deep wells, and do not allow for VLOM. The selection of another handpump has to be made according to the local conditions, as present in Ethiopia; as present in the areas where the NGO is implementing its water programme.

---

16 Target costs of handpumps, as according to the Project, are US$ 300-400 (in 1987) for a pump, complete with rods and rising main, to lift from 25 meters (Arlosoroff,1987). The Project did not indicate anything about increasing target costs with depth.

		Aquamont	ED India MkII	Kardia	Mono	Moyno	Pulsa	SWN	Vergnet	Volanta
Q (100W input)										
SWL 45 m	η	80%	65%	74%	59%	58%	41%	~70%	52%	74%
	Q	0.65m^3/h	0.53m^3/h	0.60m^3/h	0.48m^3/h	0.47m^3/h	0.33m^3/h	~0.6m^3/h	0.43m^3/h	0.60m^3/h
SWL 60 m	η	?	65%	70%	59%	?	43%	<45%	60%	70%
	Q	?	0.40m^3/h	0.43m^3/h	0.36m^3/h	?	0.26m^3/h	<0.3m^3/h	0.37m^3/h	0.43m^3/h
SWL 90 m	η	?	66%	55%	?	?	-	-	38%	55%
	Q	?	0.27m^3/h	0.20m^3/h	?	?	-	-	0.16m^3/h	0.20m^3/h
SWL 100 m	η	?	66%	44%	?	?	-	-	-	44%
	Q	?	0.24m^3/h	0.16m^3/h	?	?	-	-	-	0.16m^3/h
Suitab. for VLOM		-	-	●	-	-	●	-	●	●
Reliability		-	?	?	-	●	?	●●	●	●●
Abr.Resistance		●●	●	●	●●	●●	●	●●	●	●●
Corr.Resistance		-	-	●●	-	-	●●	●●	●●	●●
Manufact. Needs		●	●	●	-	-	●	●	●	●●
Price (SWL 60m)		?	≥US$1000	≥US$1400	≥US$1500	OP	≥US$1500	≥US$1800	~US$1600	~US$2100

Figure 29: Rating table of the different extra-deepwell handpumps.

Suitability For VLOM:
- \- poor — centralized or maybe regional maintenance necessary
- ● adequate — maintenance may be VLOM entirely, but VLOM with external assistance is more likely to succeed
- ●● good — VLOM possible.

Reliability: (at moderate discharge)
- \- poor
- ● adequate
- ●● good

Abrasion & Corrosion Resistance
- \- poor
- ● adequate
- ●● good

Manufacturing Needs
- \- cannot be manufactured in developing countries
- ● can (partly) be manufactured in developing countries with a medium industrial base
- ●● can (almost) entirely be manufactured in developing countries, partly also in countries with a low industrial base.

? No data available   OP Out of Production

It has to be realized that the existing number of handpumps installed, remains requiring centralized, or maybe regional, maintenance. This might be a bottleneck in future; but this bottleneck would worsen when the number of the Mono-handpumps would remain increasing. There may be several reasons to remain using the Mono handpump: the users' satisfaction with the pump, the familiarity of maintenance crew with the pump, standardization and spare parts availability within the agency, and national standardization efforts. Not that there has been standardized on the Mono in Ethiopia: for wells ≤45m SWL there has been standardized on the Afridev handpump; and there has not been standardized on any handpump suitable for extra-deep wells.

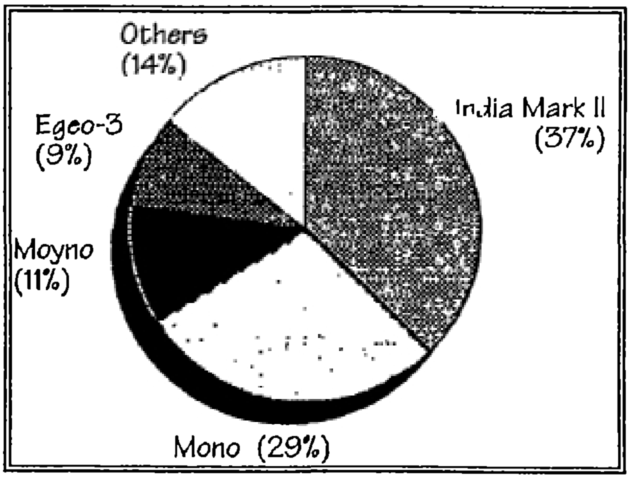


Figure 30: The share of different handpumps used in Ethiopia (UNICEF,1991).

The several handpumps used by the 38 NGOs in Ethiopia, and their share, are displayed in Figure 30.

As indicated in Figure 30, 37% (412 in total) of the handpumps used in Ethiopia are India Mark II handpumps (or handpumps made according to the India Mark II concept, such as the Pumpenboese handpump). The Mono is the second-most used handpump, with a 29% share (326 handpumps). The EGEO is a suction handpump; among the 'others' are handpumps like the Afridev, the Ethiopian made Bosewell, and SWN-80. These frequencies may indicate that it might not be without reason to remain using the Mono handpump. In-country knowledge about the handpump, and skills to repair Mono handpumps, are available. There is even a dealer of Mono handpumps in Ethiopia. However, the availability of Mono-spare parts has remained problematic. For this reason standardizing on another handpump might not have too bad consequences. Considering VLOM, the Kardia, Pulsa, Vergnet or Volanta might be chosen. Performance of both the Kardia and Volanta would allow for operation on SWLs up to 80m or more. The reliability of the Kardia has not been proven for the time being, which makes the Volanta the best option for as yet. If this pump would be disliked, the Kardia might be a good second choice. Disadvantage of both handpumps is the fact that they have still to be introduced in Ethiopia; for the time being no single one of both types has ever been installed in the country. Therefore I would advise to start with pilot projects first, if choosing one of these handpumps.

The extra-deepwell India Mark II would perform better than the Kardia and Volanta on wells deeper than ±70m SWL; however, it compromises VLOM *and* reliability. Even centralized maintenance would probably be obstructed due to the weight of the installation; and its GI rising main does not allow for proper operation in aggressive groundwater zones. On the other hand, knowledge of the standard India Mark II and the presence of suppliers and spare part procurement facilities would be big advantages of this handpump. Potential selection of the pump should be made on base of field data, which for the time being does not exist. Therefore a pilot project may be needed. However, it remains my conviction that GI risers should not be used in circumstances with low pH, such as do exist in Ethiopia.

The other mentioned extra-deepwell handpumps should not be the first choice,

although they may be cheaper. They do not allow for VLOM, have a worse performance, or their reliability has still to be proven. The SWN pumps may be promising, but for the time being their below ground components cannot be advised for usage on extra-deep wells. Next to this, there exists bad field data about the maintainability of the pump.

Hybrid handpumps might be the best choice. Besselink makes notion of a hybrid handpump using SWN-pumpstand and Volanta below ground components. By using hybrid handpumps the advantages of different handpumps may be combined. In the Ethiopian case, it might be an option to combine the pumpstand of the extra-deepwell India Mark II, and the below-ground components of the Volanta (or Kardia, if proven to be reliable). In such a way VLOM might not be obstructed too badly (although maintenance of the India Mark II pumphead might be difficult), standardization might be brought about to a large extent, and reliability would not be compromised. However, such a hybrid handpump would still need to be (field) tested intensively.

Preferably a large number of NGOs in Ethiopia would put their strengths together in initiating joined pilot projects, and selecting a suitable extra-deepwell handpump. UNICEF might play an important role, for this organization already played a significant role in the two workshops on rural water supply which have been held in Ethiopia, and in the selection of the Afridev. Only by joined agreements on pump selection and the setting up of distribution networks and delivery mechanisms, optimal results may be achieved. Only in this way, the objectives of the IDWSSD, and the improvement of rural water supplies in general, may be reached in Ethiopia (Bourbe,pers.com; KHCDP,1992; Mudgal,pers.com; Reynolds,1992; UNICEF,1989\1991\1992). An appropriate extra-deepwell handpump may play a significant role in this process -but it will never depend on the handpump solely.

7 CONCLUSIONS

The Village Level Operation and (management of) Maintenance-concept is used to make manufacturers of handpumps and implementing agencies aware of the key issue in solving maintenance problems. To solve maintenance problems community members would have to be responsible for maintenance of their own handpumps. VLOM means both the *performance* of maintenance and the *management* of maintenance on the local level. This requires both an appropriate context (the software), and appropriate technology (the hardware). VLOM has to be effected during planning and implementation.

The goals of the International Drinking Water Supply and Sanitation Decade, and the attitudes of implementing agencies, have often caused a new construction bias, in which the maintenance issue, and the required attention to the software side, did not get sufficient attention. However, effecting VLOM requires sufficient time; time for sensitization, training and education of both agency personnel and community members. Because maintenance should take place on the local level, the community attitude is of decisive importance. To learn to know this attitude, and to tune to the local context, a people oriented approach is required. The partnership approach, in which both implementors and community members are equals, offers the best perspective.

Community members should be the ultimate ones deciding about supplies. A felt need and a felt responsibility are of decisive importance. For this reason the integration with other (PHC) activities might be advantageous. Communities should both be able and willing to perform maintenance, and to pay for it. Fund raising may however be problematic. Next to this, it has seriously to be wondered whether communities would be able to pay for the replacement of handpumps. If replacement of handpumps would not be within reach, handpump projects would be worthless on the long run, and it would probably be best not to intervene.

The presence of a strong and motivated leader in communities appears to be very important.

The geographical area in which agencies work has to be limited. An area too large would seriously affect attempts to maintain handpumps centrally, or to provide for backup service. Especially the transportation costs would become too high.

A proper spare parts distribution system has to be provided; it is a basic need of VLOM that spare parts are available. Distribution should best be setup through local private stores, or local governmental/cooperative stores. Independency from implementing agencies is of prime importance, and is one of the reasons why VLOM has to be preferred over other maintenance systems.

VLOM is obstructed in several ways. Community *performance* of maintenance seems easier to effect than community *management* of maintenance. If the organizational level of the community is inadequate to manage maintenance, long-term community development may be needed. Managing maintenance by some external agency implies lasting dependency on others, and a lowered sustainability.

The level of participation which is required for both performance and management of maintenance, is high. As according to a categorization of White, VLOM requires the 9^{th} level of participation out of 10: self-reliance in the sense of using only the efforts of the community members themselves, and not appealing to outsiders for help. The probability that such a

level of participation would be reached on short term, is very small. *In practise so-called* participation has often been some costs-saving supply of labour and materials during construction only. But actual community participation in maintenance requires long-term community development in most cases.

Dispersed settlement or nomadic styles of living make VLOM impossible, because of increased maintenance costs, uncertainty of who has to maintain handpumps, or inability of users to effect maintenance.

VLOM requires handpumps which are reliable and maintainable on village level. Especially the maintainability of handpumps is of importance. The maintainability of handpumps is largely determined by three factors:

1) the accessibility of handpump components; especially of belowground components. The development of Open Top Cylinders and the use of plastics has largely contributed to this accessibility.
2) the standardization of handpump components.
3) the local manufacturing of handpump components, such as might be possible by handpump design.

Although so-called VLOM-handpumps have been developed, these pumps do still require external assistance (i.e. backup) in some cases: especially when downhole components have to be replaced, which cannot be removed through the rising main.

For the mentioned reasons 100% VLOM systems are unlikely to be appropriate. As long as at least the village level management of maintenance is effected, sustainability remains guaranteed for the largest part. Backup service could be provided through an independent area mechanic. High levels of intervention in initial stages of handpump operation and maintenance, gradually fading away with time, may be the only way towards sustainable village level operation and management of maintenance. The extent to which VLOM can be effected therefore differs over time and place, as a result of local conditions and interventions. Designing for larger extents of VLOM than actually possible would lead to the failure of projects. And failure should be prevented; it might imply an attack on the health of community members, and obstruct future interventions.

The extent to which extra-deepwells (i.e. with a Static Water Level of more than 45m) exist has often been questioned. The fact that 98% of the wells considered in the Handpumps Project had a Static Water Level of less than 50m, does not give much information about this frequency. Probably extra-deepwells occur more frequently than expected. In the case of extra-deep wells, VLOM is severely obstructed by a coincidence of constraints: e.g. diminishing discharge, increasing need for maintenance, increasing difficulty of maintenance and increasing capital/ recurrent costs. The use of plastic risers has been obstructed, especially due to variations in stress, the dynamic behaviour of plastic risers, and elongation. Problems with plastic risers have largely been solved recently, facilitating VLOM of handpumps on extra-deep wells. The number of handpump-designs, enabling water fetching from extra-deep wells, is small. At present the Volanta is probably the best extra-deepwell VLOM handpump; but it is expensive. Other extra-deepwell handpumps are the Aquamont, extra-deepwell India MarkII, Kardia, Mono, Moyno, Pulsa, SWN81/90, and Vergnet 4D; of

which the Kardia is probably the most promising one. The extra-deepwell India Mark II allows for water fetching from the deepest Static Water Levels, up to ±90m or more. However, this pump does not allow for VLOM and is sensitive to corrosion. Actual pump selection should always be made on base of actual local conditions, such as the users point of view, in country standardization and presence of handpumps.

Research on VLOM should go on. It has been assumed that VLOM is the most suitable, be it the only, maintenance system. This report highlights some critical aspects of VLOM, which are qualitative only. There is a lack of quantitative data on the performance of maintenance worldwide. Agencies and researchers have to learn to know which maintenance solutions work, and which not, on base of quantitative data: the proof from practise. It will be impossible to define absolute golden rules on maintenance systems, but it is essential that scientists and implementors realize the limitations and possibilities of the system, which is claimed to be the answer on all existing maintenance problems with handpumps.

BIBLIOGRAPHY

Arlosoroff, S. et al.
COMMUNITY WATER SUPPLY:THE HANDPUMP OPTION; Rural Water Supply Handpumps Project, World Bank, Washington D.C., 1987

Bala, P.
EXPERIENCE WITH COMMUNITY PARTICIPATION IN OPERATION AND MAINTENANCE OF HANDPUMPS IN THE STATES OF MADHYA PRADESH, TAMIL NADU AND KARANTAKA; DANIDA, New Delhi, India, 1990.

Bastemeyer, T.
MAINTENANCE SYSTEMS FOR RURAL WATER SUPPLIES: A STATE OF THE ART; IRC, The Haque, The Netherlands, 1985.

Baumann, E.
HANDPUMPS FOR RURAL AFRICA: Local Production of Handpumps in West Africa; in 'Doppelpunkt' No.2 August 1990, SKAT, pg 1-3.

Besselink, J.
IAD HANDPUMP PROJECT INVENTORY MISSION: Niger, Burkina Faso, Ghana and Kenya, 25/4/89-14/1/90; IAD, Arnhem, 3/3/90.

Besselink, J. and F. van Wilgenburg
SMALL SCALE DRINKING WATER SUPPLY SYSTEMS FOR DEEP WELLS: 2 desk studies of aspects of deepwell handpumps and alternative small scale mechanical drinking water supply systems:
part I: TECHNICAL & MANAGEMENT ASPECTS;
Besselink, J., Inter Action Design (IAD), Hengelo, 1992.
part II: FINANCIAL AND SOCIO-ECONOMICAL ASPECTS;
Wilgenburg, F. van-, Human Settlement Economics, Netherlands Economic Institute (NEI), Rotterdam, 1991.

Bron,
MAINTENANCE, THE HEADACHE OF THE DECADE; Msc rapport, Wageningen, 1985.

Bureau of Indian Standards
INDIAN STANDARD: EXTRA-DEEPWELL HANDPUMPS-SPECIFICATION; BIS, New Delhi, India, 1992.

Calorama
LOW COST WATER SUPPLY DIARY; Calorama Rural Development Service, Elburg, The Netherlands, 1992/1993.

Cleaver, F.
MAINTENANCE OF RURAL WATER SUPPLIES IN ZIMBABWE; in 'Waterlines' Vol.9 No.4 April 1991, pg 23-26.

Dekker, R.
UNE POMPE, QUELLE EAU, QUELLE ORGANISATION; Dosso, Niger, 1993.

Donaldson, L.D. and M.Karim
A VLOM SYSTEM FOR "WATSAN PROJECT" HANDPUMP EQUIPPED BOREHOLES IN NIGERIA; UNICEF, Nigeria, 1988.

Dusseldorp, D. and K.Zijderveld
PREPARATION AND IMPLEMENTATION OF DEVELOPMENT PROJECTS IN THE THIRD WORLD, 3th version, Department of Sociology of Rural Development & Department of Development Economics, LUW, Wageningen, 1990.

Elson,B. and R.Franceys
TECHNICAL BRIEF No.33/ MAINTAINING HANDPUMPS; in 'Waterlines' Vol.11 No.1 July 1992, pg. 15-18.

Evans, P.
BACKGROUND PAPER ON THE INTERNATIONAL WORKSHOP ON THE ROLE OF COMMUNITIES IN THE MANAGEMENT OF IMPROVED WATER SUPPLY SYSTEMS; held at the IRC, The Hague, The Netherlands, 4-10 November 1992.

Falkenmark, M.
RURAL WATER SUPPLY AND HEALTH: THE NEED FOR A NEW STRATEGY; Summary of papers and discussions from the UN Interregional Seminar on Rural Water Supply held in Uppsala, Sweden, on 6-17 October 1980, Scandinavian Institute of African Studies (SIAS), Sweden, 1982.

Fraenkel, P.L.
WATER LIFTING DEVICES; FAO Irrigation & Drainage Paper 43, FAO, Rome, Italy, 1986.

Fouzdar, D.K.
MAINTENANCE OF WATER WELLS- PROGRESS AND PROSPECTS; DANIDA, New Delhi, 1984.

Government of India
REPORT ON FIELD TESTING IN COIMBATORE OF THE STANDARD INDIA MARK II AND OPEN TOP CYLINDER INDIA MARK III PUMPS; Department of Rural Development, Ministry of Agriculture, in cooperation with UNDP/WB and UNICEF, New Delhi, India, 1990.

Government of Malawi
REPORT ON WORKSHOP ON NATIONAL STRATEGIES FOR OPERATION AND MAINTENANCE OF RURAL GROUNDWATER SUPPLIES· held in Mangochi, Malawi, on 1-4 december 1986, Ministry of Works and Supplies, Water Department, in cooperation with the UNDP/WB Handpumps Project and UNICEF, 1986.

Grey, D., J.Keen and J.Reynolds
U.N. HANDPUMP PROJECT REPORT DISPOSES OF MANY MYTHS; in 'World Water' Vol.10 No.4 May 1987, pg. 24-30.

GTZ
VILLAGE LEVEL OPERATION AND MAINTENANCE PUMP: OTC SYSTEM; Rural Water Supply and Sanitation Project Kurunegala, National Water Supply and Drainage Board, Department of Health, in cooperation with die Deutsche Gesellschaft für Technische Zusammenarbeit GmbH, Kurunegala Region, Sri Lanka, December 1988.

Hofkes, E.H.
GUIDE FOR HANDPUMP MAINTENANCE SYSTEMS; IRC, The Hague, The Netherlands, 1983.

KHCDP
FACTS AND FIGURES; KHCDP Biannual Report, Water Section, Addis Ababa, June 1992.

Kigingi Abubakary, K.
OPERATION AND MAINTENANCE OF SHALLOW WELLS IN MOROGORO REGION; Tampere University of Technology, Tampere, 1984.

Long, N. (ed) (1)
ENCOUNTERS AT THE INTERFACE: A PERSPECTIVE ON SOCIAL DISCONTINUITIES IN RURAL DEVELOPMENT; LUW, Wageningen, 1989.

Long, N. and J.D.van der Ploeg (2)
DEMYTHOLOGIZING PLANNED INTERVENTION: AN ACTOR PERSPECTIVE; in 'Sociologia Ruralis' Vol.29 No.3/4 1989, LUW, Wageningen.

Long, N. and A.Long (ed)
BATTLEFIELDS OF KNOWLEDGE; LUW, Wageneningen, 1992.

Madsen, B.
A COMMUNITY BASED HANDPUMP REHABILITATION AND MAINTENANCE PROGRAMME; in 'Waterlines' Vol.8 No.3 January 1990, pg. 10-12.

Mills, K.
AQUAMONT HANDPUMP, FINAL REPORT; CRL, Harpenden, England, 1988.

Morgan, P. (1)
THE HANDPUMP PHENOMENON; in 'Waterlines' Vol.8 No.2 October 1989, pg.2-5.

Morgan, P. (2)
THE ZIMBABWE BUSH PUMP; in 'Waterlines' Vol.8 No.2 October 1989, pg.24-27.

Müller, M.
PROCEEDINGS OF THE NATIONAL WORKSHOP ON POTENTIAL IMPROVEMENTS IN THE INDIA MARK II DEEPWELL HANDPUMPS DESIGN; India International Centre, New Delhi, India, December 24-25 1990.

Munguti, K.K.
COMMUNITY LEVEL MANAGEMENT AND MAINTENANCE; in 'Waterlines' Vol.7 No.4 April 1989, pg.12-13 and 20-21.

Narayan, D.
THE CONTRIBUTION OF PEOPLE'S PARTICIPATION TO RURAL WATER SUPPLY: FINDINGS FROM 122 PROJECTS; Report prepared for the International Workshop on The Role of Communities in the Management of Improved Water Supply Systems, held at the IRC, The Hague, The Netherlands, 4-10 November 1992.

Oostendorp, P.A. and D. Both
HANDBOOK FOR COMPARATIVE EVALUATION OF TECHNICAL AND ECONOMIC PERFORMANCE OF WATER PUMPING SYSTEMS; Consultancy Services Wind Energy Developing Countries, Amersfoort, November 1988.

OUP
MAINTAINING VILLAGE WATER PUMPS BY WOMEN VOLUNTEERS IN BANGLADESH; in 'Health Policy & Planning', Oxford University Press, 1991, pg. 176-184.

Pacey, A.
HANDPUMP MAINTENANCE: In The Context of Community Well Projects; Intermediate Technology Publications Ltd, London, 1977.

Pacey, A.
HANDPUMP MAINTENANCE: In The Context of Community Well Projects; Intermediate Technology Publications Ltd, revised edition, London, 1980.

Paqui, H.
MALAWIAN WOMEN KEEP THE PUMPS FLOWING; in 'Source' Vol.1 No.2 September 1989, pg. 8-9.

Reynolds, J. et al
HANDPUMPS: TOWARD A SUSTAINABLE TECHNOLOGY: Research and Development During the Water Supply and Sanitation Decade; Water And Sanitation Report No 5, UNDP/WB Water and Sanitation Programme, Washington, 1992.

Roy, S.
A ONE TIER SYSTEM: THE TILONIA APPROACH TO HANDPUMP MAINTENANCE; in 'Waterlines' Vol.2 No.3 1984.

Schoolkate, H.
SUSTAINABILITY OF HANDPUMP BASED RURAL WATER SUPPLY; Desk study in the IRC, The Hague, The Netherlands, 1991.

Shamala Devi, L.N.
A STUDY OF THE EFFECTIVENESS OF WOMEN HANDPUMP CARETAKERS
Programme in Bagepalli, Taluk, Kolar District, DANIDA, New Delhi, India, august 20, 1988.

Srivastava, J.C.
WOMEN AND HANDPUMP MAINTENANCE; in 'Health for the Millions' Vol.16 No.5 September-October 1990, pg 3-7.

Srivastava, J.C.
WOMEN AS HANDPUMP CARETAKERS IN RURAL WATER SYSTEMS; in 'Water & Wastewater International' Vol.6 No.4 August 1991, pg. 37-42.

Suciplo H. & D. O'Brien
COMMUNITY SELF FINANCING FOR WATER SUPPLY & SANITATION SYSTEMS: A PROMISING APPROACH TO COMMUNITY MANAGEMENT AND FINANCING OF WATER & SANITATION FACILITIES; report introduced by CARE Indonesia on the IRC workshop on the role of communities in the management of improved water supply systems, IRC, The Hague, The Netherlands, 4-10 nov 1992.

UNDP
THE AFRIDEV HANDPUMP: DESIGNED FOR COMMUNITY MANAGEMENT; UNDP/WB Rural Water Supply Handpumps Project, Nairobi, Kenya, 1987.

UNDP
THE NEW DELHI STATEMENT: Global Consultation on Safe Water and Sanitation for the 1990s; UNDP, New Delhi, India, 1990

UNICEF
THE FIRST NATIONAL HANDPUMP WORKSHOP; held on December 14, 1989 in Ethiopia; sponsored by the UNDP/WB; UNICEF, Addis Ababa, 1989.

UNICEF
NGO WATSAN DIRECTORY ETHIOPIA; in cooperation with the Water Resources Commission, Government of Ethiopia; UNICEF, Addis Ababa, 1991.

UNICEF
Proceedings on THE SECOND NATIONAL HANDPUMP WORKSHOP; held in Addis Ababa on 21-22 january 1992; sponsored by UNICEF, and UNDP/WB Regional Water and Sanitation Group; in cooperation with the Water Resources Commission, Government of Ethiopia; UNICEF, Addis Ababa, 1992.

Vergnet
HYDROPOMPE VERGNET 4D: LA POMPE POUR FORAGES PROFONDS; Vergnet S.A, Ingré, France, 1993.

Wahadan, L.
COST EFFECTIVE WATER AND SANITATION IN SUDAN; in 'Water Quality Bulletin' Vol.15 No.1 1990, pg. 11-17.

White, A.
COMMUNITY PARTICIPATION IN WATER AND SANITATION: CONCEPTS, STRATEGIES AND METHODS; IRC Technical Paper Series No.17, IRC, The Hague, The Netherlands, 1981.

Wierema, F.J.M.
MAINTENANCE OF RURAL DRINKING WATER SUPPLIES: The Impact Of Factors At Community Level; Faculty of Social Sciences, University of Leiden, LIDESCO, Leiden, The Netherlands, 1987.

Wijk, C. van- and J.T.Visscher
HANDPUMP PROJECTS: AVOIDING NEGLECT; in 'World Water' May 1987, pg. 44-46.

Wilgenburg, F. van-,1991: see Besselink,1992.

Wood, M.
MEETING A WATER NEED IN MALAWI; in 'World Water' Vol.12 No.8 November 1989, pg. 26-28.

APPENDIX 1: THE CRL TESTING PROGRAMME

The Consumer Research Laboratory has been involved with handpump testing and development since 1977, for the Overseas Development Administration, the World Bank, donor agencies, and manufacturers. CRL's approach reflects over 30 years of experience in the field of comparative testing of a very wide range of products. The remainder of this Appendix describes the handpump test program in detail, including the laboratory's conditions of acceptance of handpumps for testing.

CRL's facilities for testing and development of handpumps include:

- a handpump testing tower
- 4 blind boreholes, the deepest of which is 100 m, with variable water levels
- cylinder testing rig with 8 test stations
- bearing test rigs in temperature-controlled chambers
- large workshop facilities

For further information, you may contact:

Ken J. Mills OBE
Consumer Research Laboratory
Harpenden Rise
Harpenden
Herts
AL5 3BJ
United Kingdom

CRL handpump test procedures

1. Description

The test samples (a minimum of two complete samples) should be representative of the manufacturer's normal output. Wherever possible, sample pumps should be obtained through independent procurement agencies.

1.1 Manufacturer or agency: name and address of pump manufacturer and/or supplying agency